Industrial QUALITY CONTROL

VOL. IV NOVEMBER, 1947 NO. 3

Some of the 300 Executives, Engineers, and Quality Control Supervisors who attended the Management Session Program sponsored jointly by Syracuse University and the Syracuse Section of ASQC at the Hotel Syracuse, October 8, 1947. (See page 24)

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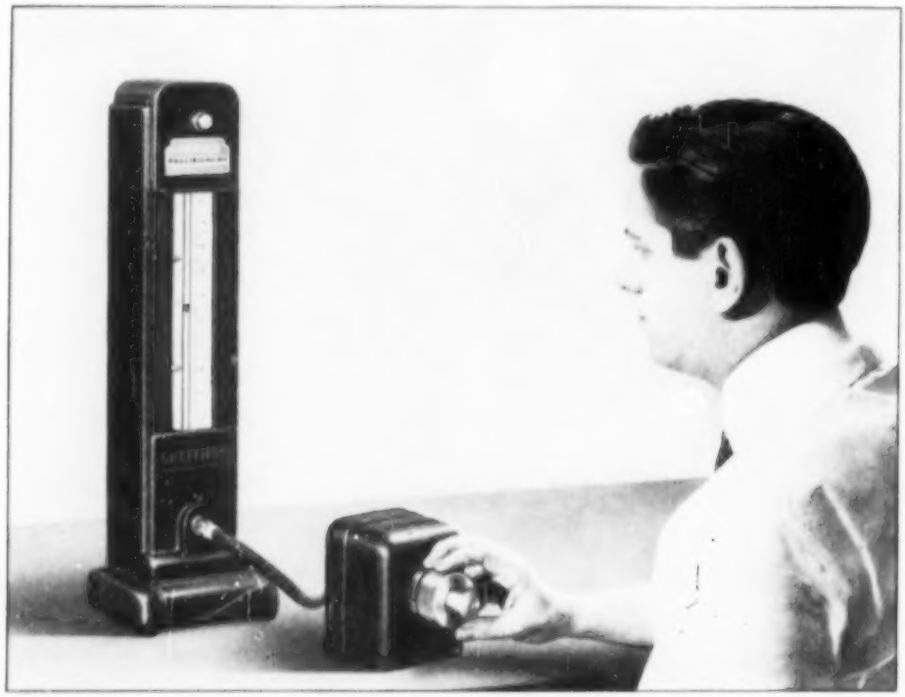

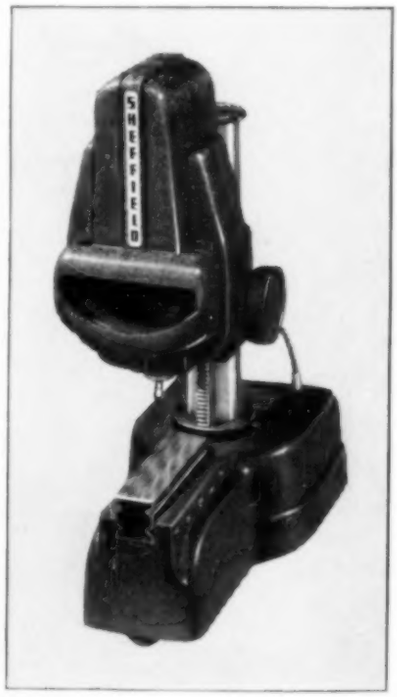

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ADVANCE NOTICE
THIRD MIDWEST QUALITY CONTROL CONFERENCE

The Third Midwest Quality Control Conference will be held at the Hotel Sherman in Chicago on November 4th and 5th, 1948.

Mr. James M. Ballowe of the Iowa Section has been chosen General Chairman of the Conference Planning Committee. Irvin W. Schoeninger of the Milwaukee Section is chairman of the Exhibits Committee, and L. S. Eichelberger of the Chicago Section is chairman of the Arrangements Committee. The Program and Speakers Committee is under the chairmanship of Professor Lloyd A. Knowler. Other officers and members of the General Planning Committee, together with preliminary announcement of the program and other details, will appear in a later issue of INDUSTRIAL QUALITY CONTROL.

Exhibit space will be at a premium at this Conference, as it will provide for only 21 exhibits. Several exhibitors have already reserved space. Arrangements for accommodating anticipated room requirements for the Conference sessions and guests have been completed with the hotel.

The general plan of the program proposes a series of introductory, educational sessions at an elementary level designed not just to **tell** people about statistical quality control, but rather to **teach** them by laboratory method the basic techniques of control chart operation. Simultaneously with each of these training classes, there will be two clinics in session. One of these will be devoted to a non-technical, general-interest presentation of various phases and applications of statistical quality control. The other will be devoted to presentation of techniques and applications of statistical methods of interest to experienced quality control personnel.

There will be two luncheon sessions with one speaker at each luncheon, but no evening banquet.

Comments or inquiries concerning the Third Conference will be welcomed by the General Planning Committee. Address: The Midwest Quality Control Conference, Box 1097, Chicago 90, Illinois.

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INDUSTRIAL QUALITY CONTROL
Published Bi-monthly
by the
AMERICAN SOCIETY FOR QUALITY CONTROL Inc.
305 East 43rd Street
New York 17, N. Y.

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Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $5.00; for Senior Members, $10.00; for Fellows, $15.00. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

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Cost of Back Issues

Most back issues can still be supplied individually at $1.00 each, but certain issues are now available only in complete volumes at $5.00 each. Volume I includes the six issues from July, 1944 through May, 1945. Volume II includes the six issues from July, 1945 through May, 1946. Volume III includes the six issues from July, 1946 through May, 1947.

Sampling Plans for Continuous Production†

HAROLD F. DODGE
BELL TELEPHONE LABORATORIES

Scope

This article discusses sampling inspection plans for continuous production in a manufacturing plant. Sampling inspection is performed under a wide variety of conditions, and it will accordingly be helpful at the outset to narrow down the field which it is intended to cover here. This is indicated in the following tabulation — items designated by an asterisk (*) in this tabulation will be the subject of principal consideration.

Kinds of Product

*Articles: such as automobiles, telephones, radios, pencils, and individual component parts thereof.
Extension products: such as wire, sheet metal, cloth.
Bulk products: such as paint, chemicals, cement.

Kinds of Inspection

Receiving
*Process
*Final

Types of Inspection Operations

Variables: measurement with recording of measured values.
*Attributes: gaging, visual inspection, go and not-go testing (mechanical, electrical, etc.).

Nature of Inspection

Destructive: 100% inspection not practicable.
*Nondestructive: 100% inspection practicable.

Lots vs. a Flow of Articles

Well organized sampling plans and procedures have been published [1], [2], [3], for use in the inspection of a product that is made available for inspection in individual lots or batches — aggregates of parts, subassemblies, finished articles, etc. collected in containers or truck loads of a size convenient for handling in the manufacturing plant.

†Presented at the First National Convention of the American Society for Quality Control, Chicago, June 6, 1947.

But suppose the product articles are manufactured by a continuous process on a conveyor or other straight line system, with individual articles following one after another in progressive assembly. What would be a natural method of inspecting the product?

Probably inspection would start as a 100% inspection, with examination and testing of each article as it came to a designated inspection station. This might well include several inspection operations: mechanical tests, as for spring tension; electrical checks; dimensional checks with appropriate gages, and visual inspection for surface defects.

Now suppose that, after inspecting each and every article for a period of time, it were observed that, say, in the last few hundred articles no defects have been found for one particular feature — a dimension, subject to check with a special gage. It might then appear perfectly logical to take a chance and economize on this inspection operation by inspecting, say, one in every five articles, or even one in 10, for this particular feature. Then so long as no defects were observed, this sampling inspection could be continued. But if, while sampling in this way, a defect suddenly appeared, what then? A natural procedure would be to reinstate 100% inspection, to notify production, particularly if a second defect appeared, to continue the 100% inspection until again a run of a substantial number of articles was found to be clear of defects, and then to reintroduce sampling. The same procedure could be used for other characteristics that were found to be practically clear of defects. However, for characteristics having an unacceptably high percentage of defects, 3%, 5%, or 10% it would be natural to continue 100% inspection, keep production informed of the unsatisfactory situation, and urge correction in process to produce acceptable quality on the line.

These considerations led to the development of the first plan to be described, referred to in practice as the "random-order" plan.

First Plan: Random-Order Plan

The random-order plan by the author [4] presumes a continuous flow of

1. consecutive articles (Procedure A), or
2. consecutive lots or batches of articles (Procedure B),

offered to the inspector for acceptance in the order of their production. The intent of the plan is to assure a limiting value of average percent defective which will not be exceeded in the product after inspection. This limiting value of percent defective, termed the "Average Outgoing Quality Limit (AOQL)" is assured by the plan so long as we exclude certain peculiar types of situations not commonly encountered in practice, for example, where the process percent defective is varied up and down in a repetitive pattern to match the periods of sampling and of 100% inspection.

Procedure A of the random-order plan, applicable to a product of consecutive articles, is as follows [4]:

(a) At the outset, inspect 100% of the units consecutively as produced and continue such inspection until i units in succession are found clear of defects.

(b) When i units in succession are found clear of defects, discontinue 100% inspection, and inspect only a fraction f of the units, selecting individual sample units one at a time from the flow of product, in such a manner as to assure an unbiased sample.

(c) If a sample unit is found defective, revert immediately to a 100% inspection of succeeding units and continue until again i units in succession are found clear of defects, as in paragraph (a).

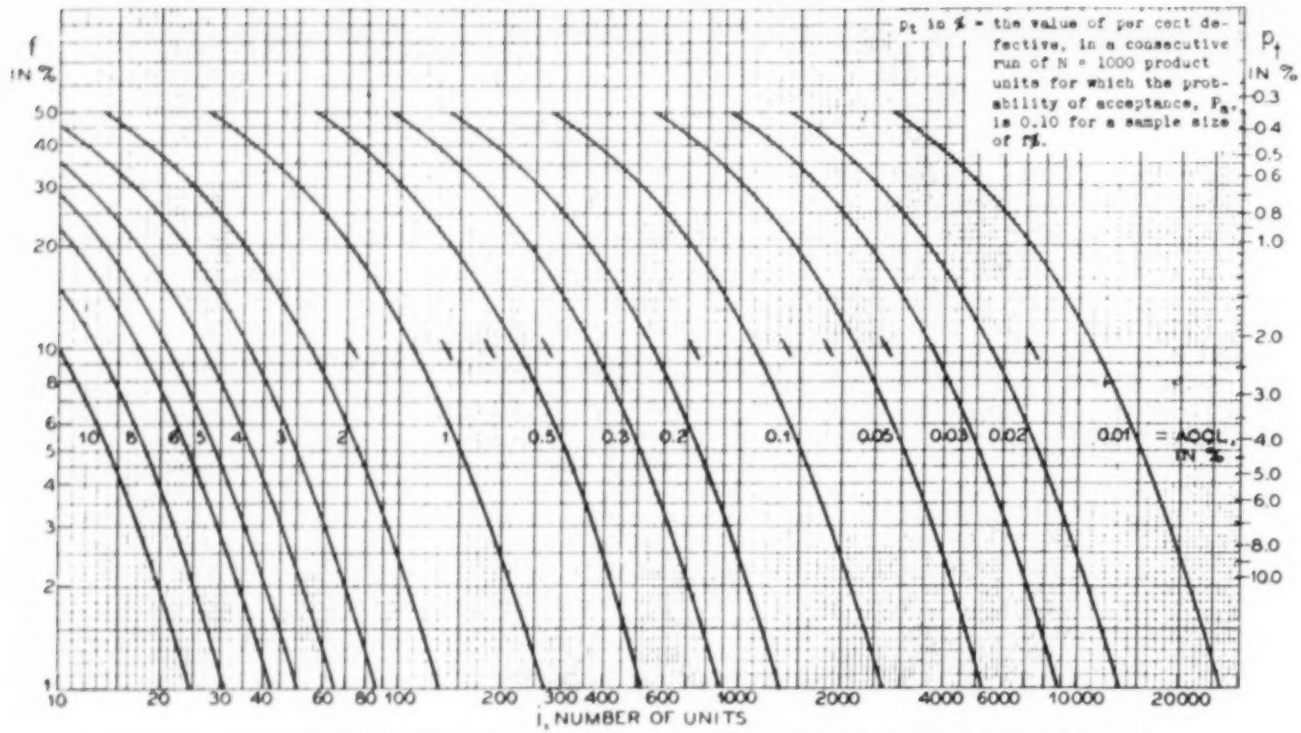

FIGURE 1. CURVES FOR DETERMINING VALUES OF f AND i FOR A GIVEN VALUE OF AOQL.

(Reproduced from "A Sampling Inspection Plan for Continuous Production", H. F. Dodge, *Annals of Mathematical Statistics*, Vol. XIV, No. 3, September, 1943.)

(d) Correct or replace, with good units, all defective units found.

This plan is defined by the two constants, **f** and **i**, which can be altered at will, and for any particular combination of values of **f** and **i** there will be a specific value of AOQL. Suppose, for example, it were desired to have a plan such that the **average** outgoing quality after inspection would be not worse than 1% defective (AOQL = 1%). Referring to Fig. 1 this could be obtained by choosing **f** = .10 (i.e. 10% of units inspected during sampling) and **i** = 109 (number of units in succession to be clear of defects in order to start or to renew sampling). From the 1% AOQL curve of Fig. 1 it is noted that the same AOQL value would be obtained by other combinations of **f** and **i**, such as **f** = 5% and **i** = 151, and **f** = 2% and **i** = 212. Certain considerations [4] enter into the most advantageous choice of **f** and **i**, — for example, it will be apparent that the use of too small a value of **f** will increase the chances of passing unnoticed a short run of poor product. Some idea of the risk involved is shown by the right-hand scale of Fig. 1. The most commonly used values of **f** are 5%, 10%, and 2% — values of less than 1% are usually avoided.

This plan has been used rather extensively and has been found most effective when administered in such a way as to provide an incentive to clear up faults in process promptly. Such an incentive may be provided, for example, by requiring the production department to perform the necessary 100% inspections when defects are encountered. To this end, the following administrative procedure has met with good success: A regularly assigned process inspector performs all sampling inspections required; if additional assistance is needed when it becomes necessary to revert to 100% inspection or in performing the initial 100% inspections required, the process inspector notifies the foreman in charge of the production line; the foreman must then immediately assign temporary inspectors who are acceptable to the process inspector and who work under the jurisdiction and supervision of the senior process inspector on the line; when sampling inspection is reinstated, the temporary inspectors return to their regular assignments. The following are examples of the plan where this procedure was used in a government plant during the war:

Example 1. Covering one dimension: over-all length of an ammunition component. Method of inspection: dial gage. Inspection station: at end of loading line during 100% visual inspection. Plan: 1% AOQL, **f** = 2%, **i** = 210.

Example 2. Covering three dimensions treated collectively: length, depth of crimp, and diameter of a small component. Method of inspection: three gages, — go, not-go. Inspection station: at end of loading line following 100% visual inspection. Plan: 1% AOQL, **f** = 10%, **i** = 110.

Example 3. Covering two classes of defects separately, major and minor: ten specifically designated defects (4 major, 6 minor) of sewing, stitching, and tie cords of bags. Method of inspection: visual. Inspection station: immediately following final check weighings. Plan for major defects: ¾% AOQL, **f** = 5%, **i** = 200. Plan for minor defects: 1½% AOQL, **f** = 5%, **i** = 100.

The following two examples cover applications of the random-order plan to a particular type of electrical apparatus produced on a moving conveyor line:

Example 4. Covering one electrical test: 500 volt a-c breakdown

test on base assembly of a piece of electrical apparatus. Method of inspection: electrical test. Inspection station: designated point on the conveyor line. Plan: ½% AOQL, $f = 5\%$, $i = 305$.

Example 5. Covering six characteristics treated collectively, on same base assembly as Example 4: condition of plunger, height of plunger, freedom of movement of plunger, perceptible movement of plunger below level of operating surface, correct assembly of bracket in housing, and freedom of operation of wheel. Method of inspection: visual and manual check. Inspection station: designated point on the conveyor line. Plan: 2% AOQL, $f = 5\%$, $i = 75$.

In some cases, the amount of inspection is such that one inspector has time to check the product at two or more inspection locations on the conveyor line. As a result, he may visit each location periodically and take a group sample, as, for example, 15 minute intervals and group samples of 5 units each. The selection of small group samples rather than individual units one at a time from the line is permissible under certain restrictive conditions [4]. When a defective is found, he calls a utility inspector to do the required 100% inspection. An immediate attempt is made to eliminate the cause when a defective condition is found.

Example of Procedure B of Random-Order Plan — Procedure B of the random-order plan [4] incorporates modifications of procedure for adaptation to a product consisting of a flow of consecutive sublots or batches of articles. Here **f** is the fraction of each sublot inspected during sampling. When a sample unit is found defective, 100% inspection is started for the remainder of the sublot and is continued even into succeeding sublots, if necessary, until **i** inspected units in succession are found clear of defects. Mr. E. E. Folsom, Engineer of Quality Control, Appliance and Merchandise Department, General Electric Co., and Mr. C. D. Ferris, Quality Control Engineer, have furnished an interesting example of application of this procedure. The product consists of molded clock cord sets, packed 500 to a box. Even though all plugs were 100% inspected during the process in a combined cleaning and inspection operation, plugs containing defects of a serious nature were getting by. It was imperative that the percentage of such plugs be held to an extremely low value. Accordingly, it was decided that protection at a level of 0.10% AOQL was necessary, and the following plan was introduced after a 100% check of the cleaning inspectors' work revealed a spotty type of quality:

> Boxes are presented to the inspector consecutively in the order of production. A sample of 50 sets (10%) is selected from each box of 500. If no defects are found, the box is passed. If a defect is found, the remainder of the box of 500 is inspected and additional boxes are inspected 100% until two complete boxes in succession are found to be clear of defects.

Note that this procedure invokes the 100% inspection phase of the plan in such a form that it is readily understood by the line inspector and easily carried out. This is a modification of the usual provision for a fixed value of **i** (such as $i = 1100$ for an AOQL of 0.10% and $f = 10\%$, instead the number of sets to be found clear of defects may vary from 1000 to 1499, and, in general, would be expected to be greater than 1100. With the plan operating 10 months, the actual outgoing quality based on a quality audit of outgoing shipments, showed only 19 such defects in samples totalling 34,400 cord sets, that is 0.055% defective. During this period, it is estimated that the percentage of defective material reaching the package stage was something like .3 of 1%. Thus the value of only .06% defective in outgoing shipments was considered proof of the efficacy of the plan. It has been pointed out further, that when very bad material reached the package stage, as occasionally happened, the outgoing quality for this segment was practically free from defects.

Second Plan—SPC Plan of Wald and Wolfowitz

Wald and Wolfowitz have developed three sampling plans for continuous production [5] designated SPA, SPB, and SPC, of which SPC is selected for consideration here. This plan deals with a stream of successive articles or units, as does Procedure A of the random-order plan. The stream of units is considered as a series of successive segments of N_0 units each, and the procedure is as follows: In each segment, start inspecting a fraction **f** of the units, i.e. 1 unit at random from each successive group of $1/f$ units. If at any time, while sampling a segment in this way, a total of M^* defects are found, where

$$M^* = f(AOQL)N_0/(1-f),$$

inspect 100% the remainder of the N_0 units in the segment, otherwise continue sampling through the entire segment of N_0 units. Repeat the procedure for the next segment of N_0 units.

Example: $AOQL = 4.5\% = .045$; $f = 10\% = 0.1$; $N_0 = 1000$;

$M^* = (.1)(.045)(1000)/(.9) = 5$.

This plan limits the extent of 100% inspection to the remainder of units in a segment, and always starts sampling anew with each segment. The particular choice of N_0 affects the "local stability" of the plan. For example, if, in the above case, N_0 is made very large, say 5,000, little protection will be provided against a temporary wave of very poor quality such as a run of 500 units averaging 20% defective, whereas if N_0 is made small, say 200 or 400, the protection will be high but at the cost of more inspection. No specific guide to the choice of **f** and of N_0 is given by the authors.

Third Plan—Single Sampling AOQL

The third plan is the usual AOQL single sampling plan such as is covered in published sampling inspection tables [1]. This has been used extensively for conveyorized products. The procedure consists in designating some segment of successive units, 100, 200, 500, etc. as a lot, selecting and inspecting a sample of n units from each such lot, allowing the lot to pass if the number of defectives found in the sample is c or less, but requiring 100% inspection of the lot if more than c defectives are found. With this procedure, the AOQL is given by the relation:

$$\text{AOQL (in fraction defective)} = y(1/n - 1/N)$$

where

y = a constant depending on the value of c; i.e., 0.378 for $c = 0$,

0.841 for c = 1, etc. (see Ref. [1]).
n = sample size in number of units.
N = lot size in number of units.

With this plan, provision must be made to hold the segment or lot of N units available until its sample has been inspected, in case it becomes necessary to inspect it 100% because of unfavorable sample results. This is an inconvenience, though not unsurmountable, for a conveyorized product. The inconvenience is minimized by selecting sample units and inspecting them as the parade of units passes the inspection station, for if the observed number of defectives exceeds the allowable number, c, at an early stage, only a portion of the lot will have passed on, and will need to be recalled, and production can be notified promptly in the interests of early corrective action which will benefit subsequent product.

If production is continuous but not conveyorized, as for punch-press or machined parts, it is usually easier to collect the parts in trays or pan loads, often one hour's production, or two hours' production, and treat the production for the designated period as a lot, to be sampled as such in accordance with published AOQL plans, either single sampling or double sampling.

The advantage of using the published tables of single sampling AOQL plans [1] lies in the fact that, whether the product is conveyorized or not, the sampling tables tell how large a sample (i.e., what fraction $f = n/N$) and what c to use, in order to **minimize** the over-all amount of inspection for the current process average level of percent defective coming to the inspector.

Suppose it were decided to inspect a sample of n = 25 units per hour out of an hourly production of 200, and to allow c = 1 defective in this sample of 25. With the procedure under discussion, this plan would have an AOQL of 3% defective (computed value 2.9%). If, however, the process average percent defective were ½%, the published tables [1] indicate that the same AOQL would be assured by taking a sample of n = 12 units and allowing c = 0 defectives, and that this plan would involve less over-all inspection (inspection of samples plus 100% inspection of the remainder of those lots that fail to be accepted by sample)—a saving of about 15% in this case.

Fourth Plan—Double Sampling AOQL

The fourth plan,* double sampling AOQL, is similar in all respects to the third plan except that it involves double sampling instead of single sampling. It constitutes an adaptation of the AOQL double sampling plans designed for lot inspection and covered in published sampling inspection tables [1].

For a conveyorized product this plan is generally less desirable than the single sampling AOQL plan, primarily because of the practical difficulty of extracting second samples when needed. The device of extracting units simultaneously for both a first and a second sample is often found advantageous when double-sampling is used.

However, for nonconveyorized product, where the product is made available in completed segments or lots, it is the author's experience that a double sampling AOQL plan is generally preferred to a single sampling or a multiple sampling plan under the conditions and with the inspection facilities that exist in the typical manufaucturing plant.

Fifth Plan—Control Chart and Variables Inspection

Use of the control chart, particularly with modified control limits [6], and a plotting of averages and ranges of samples of 5 selected periodically from the production line provides a plan of special interest for dimensional characteristics. This plan has been used with particular success for controlling processes, for it provides continuing information on the variability and the level of process quality that cannot be obtained in any other way. When used likewise for acceptance of the product itself, this procedure commonly calls for holding product turned out between successive samplings, and 100% inspection of this product if either a sample average or a sample range falls outside its control limits. For equivalent protection to outgoing quality, a small sample inspected by variables, for example, has been variously estimated to be the equivalent of a sample of 2 to 4 times as large inspected by attributes, although the costs of handling the data are, of course, much greater.

Patrol Process Inspection

Mention should be made of a general type of inspection procedure, here designated as patrol process inspection, which is intended to provide a continuing check of the process. Used in various forms in the inspection programs of many manufacturing plants, this is usually a simple procedure not based on statistical methods and technical sampling theories. One such procedure, provided with definite routines to be followed by inspectors and used extensively in the shops of a large electrical manufacturing concern, has been published by Manuele [7] and is referred to as "first piece and patrol inspection."

Procedures of this general type are particularly effective in controlling quality with respect to defects that occur without warning on practically every unit produced, that is, defects that are caused, say, by a sudden fault in process such as a change in alignment of machine tool parts or the use of a box of wrong parts in assembly, in contrast with defects that occur on a small percentage of the product in a hit-or-miss fashion as, for example, those resulting from momentary inattention or carelessness of an operator.

The "first piece and patrol inspection" method [7] consists in inspecting one part very thoroughly after the machine or process has been adjusted or set up to the satisfaction of the operator, to ascertain that a typical part is meeting the particular requirements involved. Following this, the inspector returns periodically, perhaps several times a day, observes the operation and checks one or more parts to assure himself that the machine or process operation continues satisfactory. If satisfactory, the process is permitted to continue. However, if one or more defective parts are observed, the operation may be stopped, and an adjustment made in the process or machine. Parts made since the last visit may be subject to recall and detailed inspection if the nature of the defects warrants this action. The success

of this type of plan rests largely on the degree to which the entire procedure is organized into a well-defined system, understood and adhered to by operator and inspector alike.

Remarks

Several sampling plans have been outlined for use in the inspection of a product consisting of discrete articles manufactured in essentially continuous production.

The basic objectives of such plans as applied in the manufacturing plant are (a) to force control of the production process and (b) to correct product itself insofar as necessary to assure a desired degree of conformance to requirements. Such plans are most effective when installed as close as possible to the source of process faults, and when provided with an incentive to correct such faults promptly once they are in evidence. Such an incentive is provided, for example, if the production group is assigned the task of performing any 100% corrective sorting of the product that sampling inspection shows to be necessary. Above all, inspection results should be obtained promptly and information on faults furnished promptly to production, all with a view to forestalling the continuance of unwanted irregularities and the production of scrap.

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The Modern Tower of Babel

LEONARD A. SEDER

QUALITY CONTROL ENGINEER, GILLETTE SAFETY RAZOR CO.

SCENE: The Superintendent's Office, Monday morning. Present are: Joe—the foreman of rivets; Andy—the chief inspector; Mac—the cost accountant; Bill—the design engineer; Frank—the planning supervisor; Carl—the superintendent.

CARL: This meeting is to find out what's wrong with our P-98 beer can-opener. Why aren't we getting the production out? We've never met the quota and last week we didn't even make 50% of the quota. What in the h—l is wrong?

FRANK: We aren't getting the rivets. That's why we got Joe up here.

CARL: Well, Joe, how about it?

JOE: Aw, we're getting them out, but the d—d inspectors are too tough. There's a new guy down there and he won't pass anything.

ANDY: Listen, Joe, that guy may be new, but he knows his stuff. He's had ten years of experience. I'd trust him on any part in the plant.

JOE: Yah, but he waits until we've got a whole box full of scrap before he comes around. Why doesn't he come around more often so we won't lose a couple of hours work?

ANDY: Why don't you guys make 'em right? Then you won't have to scrap 'em!

JOE: All we're supposed to do is make 'em. You're the guys who scrap 'em. I wish you'd have him come around more often, though.

ANDY: That guy's got seven other jobs to inspect. He can't come around every five minutes. (Turning to Superintendent) Anyway, like I was telling you the other day, Carl, we've got to have more inspectors on this job.

CARL: Well, if we've got to have more inspectors, why don't we get them?

MAC: The budget won't stand it. Our indirect labor is already way too high.

FRANK: Never mind the inspection. Like Andy says, why can't you make them good enough so they'll pass inspection?

JOE: What?—With only five thousandths tolerance? That's too d—d tight! We ought to have ten thousandths.

CARL: That's up to the engineers. What do you say, Bill?

BILL: It's the same old story, Joe, and you know it. Five is plenty for that operation. If we gave you ten, you'd be all over the lot.

FRANK: That's right, the more you give them, the more they want. If you'd get after some of those guys on the machines, and stop them from fooling around, you'd get the stuff out.

JOE: Oh yeah? Don't forget we've got a union in this place!

CARL: We're not getting anywhere. How about it Joe, what are you going to do about this rivet?

JOE: Well, I think that this job should go on to a grinder. We can't hold those tolerances in our place — not with the way the inspectors are so fussy. And those old machines —.

MAC: That would double the cost of this part. We've got to cut down costs, not increase them — especially now.

CARL: Does anybody know what tolerances Joe's machines can hold?

FRANK: Well, the manufacturer doesn't guarantee them for any special limit, but I figure they ought to be able to hold three or four thousandths easily.

JOE: Huh? Maybe when they were new! They're twenty years old now and falling apart!

ANDY: Wait a minute, it seems to me that new quality control guy said something about finding out the "machine accuracy" on that rivet job.

CARL: Can he do that?

ANDY: I think so, why don't I call him down?

CARL: O. K. Go ahead.

CURTAIN TO DENOTE PASSAGE OF FIVE MINUTES

(Enter Pete — the Quality Control Guy)

(Head nods and "how are yuh's" are exchanged)

CARL: I understand you've been investigating this P-98 rivet job. Have you found out anything?

PETE: Yes sir, I have. I've got all the dope right here.

CARL: Well, let's hear it.

PETE: This is a fairly simple problem. I've taken measurements on some of the rivets and I've made up a quality control chart to see what's happening. The first thing I found was that the job was out of control.

CARL: Well, we all know that.

JOE: Sure, there's too many variables to be able to keep it under control all the time.

PETE: I think my use of the word "control" is a little different from yours. We recognize that a certain amount of variation is inevitable because of the many variables that go into any machine or process. We can go further, however, and make measurements on the product which will tell us just how much that should be for any particular job. We call it the "machine capability." In this case, for instance, if this machine were being operated properly, all the points would stay within these dotted lines— which represent the machine capability. Actually, they keep jumping, first over the top line and then under the bottom, like a drunken driver, lurching from one side of the road to the other.

CARL: You mean that the operators are doing something wrong?

PETE: In a sense. If these points stay inside the lines, then there is no particular reason why one bunch is a little higher or lower than the next. It's just a matter of chance. That's what we call a "controlled process." The fact that they hop outside of these lines means that there is some particular reason — which can be found out — why that is happening.

ANDY: What's the reason?

PETE: In this case, fortunately, it's very simple. The machine capability here is just about six thousandths. That means that it just isn't capable of meeting the tolerance of five thousandths that is required. Now the operator is trying to do a good job, so whenever he happens to find a piece that is near the high limit, let us say, he shifts the setting of the machine. But the six thousandths variation due to the machine is still there, so this throws some pieces below the low limit. When he finds that out after a while, he shifts upwards and then it runs on the high side. And so on.

JOE: Well, what can we do about it?

PETE: If Bill here will revise the drawing to allow six thousandths instead of five, I can show the operator how to keep a chart so that he'll almost always be able to stay within tolerance or know positively when a resetting is needed. Because a controlled process is predictable we can be quite certain that all the rivets will be within .006". More than that we can say that 98% of them will be within the .005". As it is now, the overall variation is .009".

FRANK: You mean to say that by opening up the tolerance, the product will be better than it is now?

PETE: Strange as that may seem, it is true. Of course, he will have to keep the control chart.

CARL: Won't that cut down on his production ?

PETE: Not on his **good** production!

ANDY: Well, if all the parts are going to be good, we should be able to cut down on our inspection instead of increasing it.

PETE: That's right. When we get this working, you won't need any more 100% inspection on the bench. The floor inspector can come around **less** often and merely double-check the opertor. As long as he is satisfied that the operator is keeping the chart right, he can accept the work without further inspection.

MAC: That sounds like less overhead to me; I like it.

PETE: I've figured out that the elimination of scrap and reduction in inspection will save 30% of the cost of the rivet. Then, of course, there's the advantage of being able to meet your quota.

JOE: This sounds like the stuff I've been looking for. When can we start?

FRANK: Say, we ought to do this to other machines. Then I can put the toughest jobs on the best machines.

CARL: What about opening the tolerance, Bill? Can the design stand it?

BILL: Sure. The only reason we put on **five** was that we wanted to be sure of getting them within **ten.**

QUALITY CONTROL IN THE CHEMICAL INDUSTRY

V: Quality Control in the Synthetic Rubber Industry*

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The manufacture of synthetic rubber constitutes today a sizable segment of the chemical industries in this country; it is also one of the newest segments. Developed largely during the war when supplies of natural rubber were cut off, the synthetic rubber industry grew rapidly until in 1946 the total production exceeded 1,500,000,000 pounds.

For the most part, the operation of synthetic rubber plants was controlled and coordinated by various government agencies. Research and development, too, were coordinated and findings made available to all participants in the program. These circumstances, plus the fact that war-time demand made both huge quantity and high quality of production an absolute necessity, provided a splendid opportunity for the utilization of modern principles of statistical quality control. Not all plants used statistical quality control in the same manner, but where it was applied it was generally found to be instrumental in improving quality and uniformity, and lowering costs.

Control of Product Quality

Shortly after our entry into World War II, tire manufacturers and other consumers of rubber were compelled to make the transition from the natural to the synthetic product. It was especially important that the new synthetic product (GR-S) be uniform in all respects, so that lots produced at different times or at different plants would behave similarly in all operations at the consuming plant.

One of the first statistical applications employed in attacking the problem of uniformity was the use of distribution curves depicting the distribution of important properties of the product over a month's time.

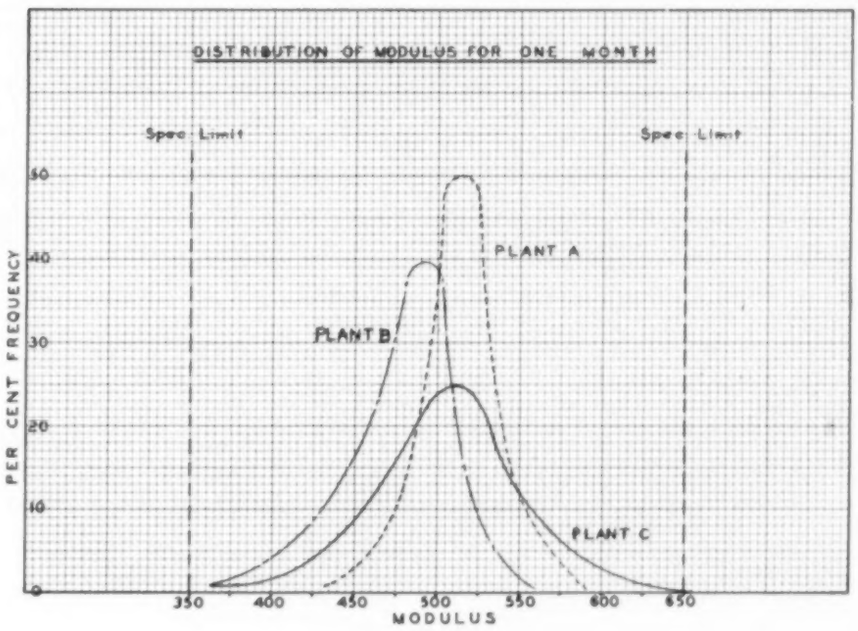

FIGURE 1.

Curves for several plants were drawn on one graph, together with vertical lines indicating specification limits (Figure 1). These graphs were assembled monthly and distributed to those interested in and responsible for quality. In this manner the proper people were kept informed of the following important items:

1. The relation of quality characteristics to specification limits—whether in the center of the specification limits or dangerously close to one side, or partially outside the limits;

*This article is based on a group of lectures delivered at a course on "Quality Control in the Chemical Industry" given at Rochester Institute of Technology. The investigations were carried out under the sponsorship of the Reconstruction Finance Corporation, Office of Rubber Reserve, in connection with the Government's Synthetic Rubber Program.

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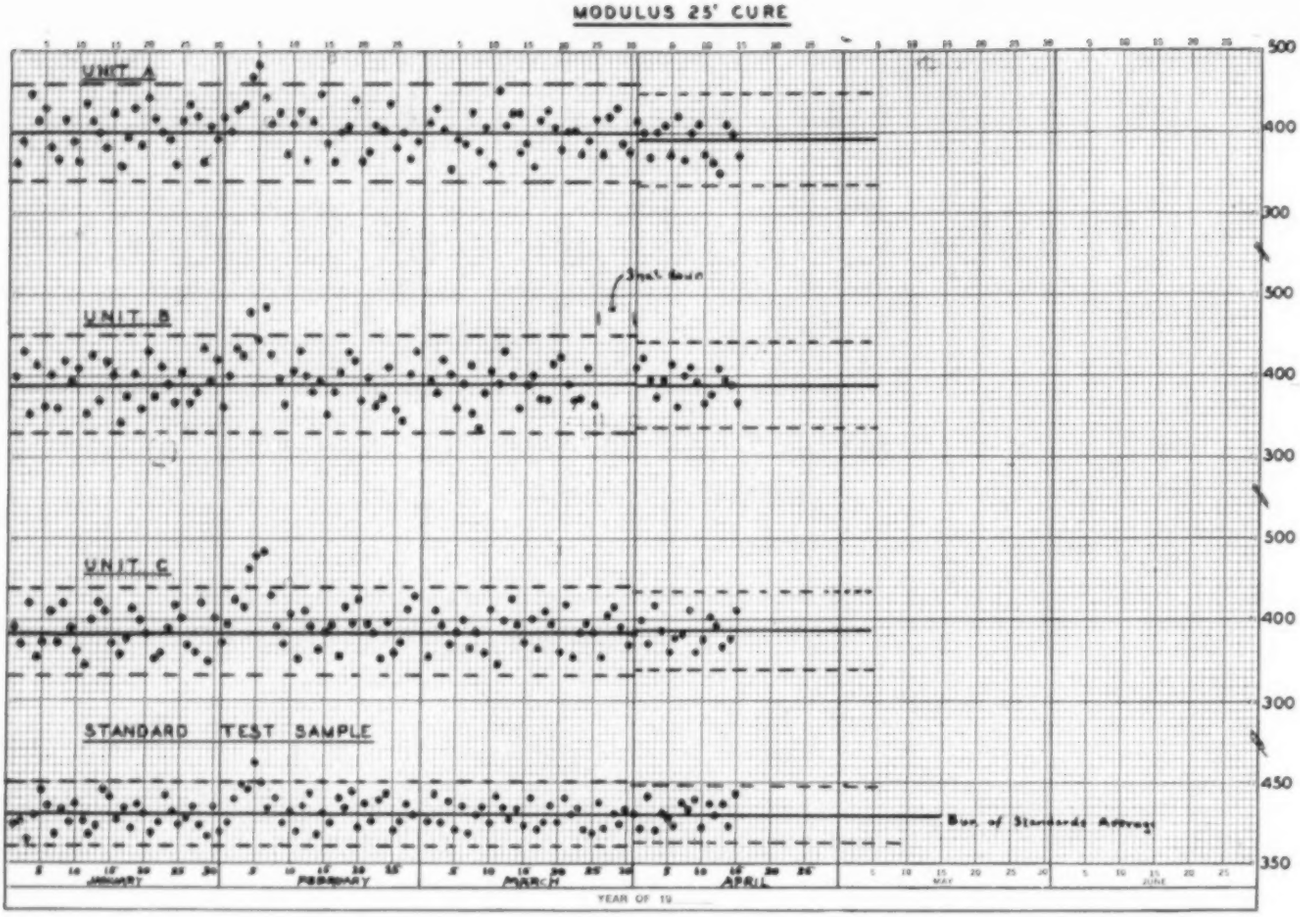


FIGURE 2.

2. The narrowness or broadness of the distribution curves, as compared with the width of the specification limits, and as compared with the curves of other plants;
3. The general average of the quality characteristics as compared to other plants;
4. The progress of each plant from month to month.

As conditions became more favorable it was agreed to adopt narrower specification limits so as to further increase uniformity. By drawing the new limits on the graphs of distribution curves, it was possible to ascertain at a glance which properties would present no difficulties and which would require attention in order to meet consistently the narrower specifications. Graphs were also drawn showing the standard deviation of each quality characteristic as measured for a period of one month. These monthly standard deviations, plotted on special graph paper (one year by months) showed the progress being made for each quality characteristic, as compared both with previous months and with the other plants.

Control charts were soon introduced (Figure 2), and all of the important quality characteristics were plotted in this manner. For the most part single values were plotted, rather than the averages and ranges of small groups, since tests were usually conducted once each day, and it was found convenient to plot points daily on special graph paper (six months by days).

The charts were especially useful in showing the effect on quality of changes in equipment or operational procedures in the plant. They were invaluable, too, in demonstrating the relationship between laboratory testing and apparent variations in quality—a point which will be amplified in a later section.

Process Control

The output of a machine producing metal parts can usually be inspected and tested in a matter of hours or even minutes. Many chemical tests, on the other hand, require several days to run. It is obvious that for proper quality control in chemical industries it is necessary to control further back in the process, and not rely exclusively on finished product tests. Raw material tests may be considered as a part of **process control.**

Control charts have been extensively used in process control. A number of illustrations will be given.

Raw materials are tested for their important characteristics, and the test results plotted in the usual control chart form. On the same charts are plotted the producer's tests for the various lots. Where producer's tests are judged to be reliable, it has been found expedient to reduce the frequency of raw material testing and place greater

dependence on the results obtained by the producer. In this manner the cost of laboratory testing can be reduced with safety.

In the synthetic rubber process a number of different ingredients are charged to a large pressure vessel and heated for a certain period of time. As the proportions charged are critical, it is necessary to control metering very carefully. Each meter is calibrated periodically—perhaps once a day—by metering 100 gallons of material into a special calibration tank where the true volume may be read with accuracy. The calibration is usually carried out in triplicate, and the average of the calibration readings and the range plotted on a control chart. If the points are not in control, the calibration is repeated; if these results are confirmed, a correction factor is applied until the meters can be dismantled and adjusted. The control charts provide a complete history of each meter. If a meter is a consistent offender it may require overhauling or replacement. Sometimes two makes of meters are performing the same job; when replacement is in order, or when new meters are needed for other jobs, it is an easy matter to ascertain which make of meter has shown better precision or has given less trouble.

When the ingredients have been mixed, it is necessary to control the temperature within narrow limits by automatic instruments so that rate of reaction will not vary from one batch to the next. The yield, also, is critical; unlike most chemical processes, a high yield is undesirable, for it adversely affects quality. It has been found useful to plot on one graph sheet control charts of percent yield, average temperature, and maximum temperature (as read from the temperature recording instruments). If the yield is found to be too high, and at the same time the average temperature is also too high, the fault obviously lies in temperature control. (It is known that an increase in temperature results in a definite increase in reaction rate). If the temperature is satisfactory, then charging may be at fault, or the quality of the raw materials may have altered somewhat. The **maximum** temperature indicates the precision of temperature control. When this value is too high, the control instrument may need adjustment, or the reaction vessel may need cleaning. Some plants have adjusted a schedule of cleaning reaction vessels by observing from the control chart when the maximum temperature is getting out of control. This system has been found less costly than cleaning vessels on a fixed time schedule.

After the reaction has taken place, the batch must be steam-distilled to recover unreacted materials. Any residual unreacted material left in the final product represents both a monetary loss and a reduction in product quality. Control charts of percent residual unreacted materials have been kept for each recovery unit. When values are out of control or show an upward trend, investigation follows. Often it is found that some part of the recovery system requires cleaning, or perhaps a steam flow-meter may need adjustment. The control chart thus acts as a sensitive warning signal.

After the recovery operation, the next step is the coagulation of the suspension of rubber particles which results from the earlier steps in the process. The coagulated material must be thoroughly washed to remove inorganic salts which appear as the "ash content" of the rubber. Control charts of ash content have been kept for each coagulation unit. It has often been found desirable to vary operational procedures or install different types of experimental equipment in an effort to reduce the ash content. The control charts show instantly the effect of each change in procedure or in equipment. They provide a concise answer to questions regarding the most effective procedure or the advantages of a new piece of equipment.

One of the last steps in the process is the drying of the rubber. Excessive moisture is undesirable, and strict control is maintained over the output of each dryer. Control charts of moisture content, posted in the office of the foreman or supervisor in charge of the drying operation, have served to keep the proper people informed of the operation of each dryer, especially with regard to slow trends which might otherwise creep in unsuspected.

Many other charts which have been found of value are concerned with costs rather than quality. For example, a chart has been kept of the average weight of the finished GR-S bales. Each bale is shipped in an expensive multi-ply bag, and the lower the weight per bale, the greater the bagging cost per pound of GR-S. The control chart helps keep bale weights up to the desired level by immediately calling attention to any divergence from standard.

On other charts are plotted steam consumption per pound of product, chemical consumption for servicing units (such as brine softeners), and raw material consumption per pound of product. The latter are often plotted in "running averages" of 10, so as to smooth out the large variations which occur from day to day because of the inherent roughness of inventory measurements. Unfavorable trends or persistent overconsumption of a particular material can be quickly spotted by means of these charts. Running averages were found very effective for inventory measurements, where ordinary control charts were found useless because of the extreme inaccuracy of the data. For other purposes they were interesting in that they demonstrated certain trends and cyclic variations which were otherwise undetectable. However, they were not considered as a satisfactory replacement for the ordinary control charts in general.

Coordination of Laboratory Testing with Quality Control

In measuring the dimensions of metal parts with a precision instrument such as a micrometer, it is generally assumed that the measuring device is entirely accurate. If off-specification pieces are found, the process is investigated first; usually the micrometer is the last suspect to be examined. Chemical testing, on the other hand, is fundamentally different in this respect. Chemical tests ordinarily require several steps, each of which is subject to greater or lesser errors; when a strange result is obtained, the entire test is usually repeated. When off-specification material is found, sometimes the test is first on the list of suspects, rather than last. This is especially true of tests which measure **performance** of

products — tensile strength, hardness, abrasion resistance, flexing life, for example. These tests are largely empirical in nature and depend upon highly uniform testing conditions for meaningful results. There may be large variations in results depending on the temperature, humidity, the particular apparatus used, the person performing the test, or even less tangible factors.

The testing of rubber is an especially complex procedure, and the inherent errors are large. Thus it has been found of the greatest necessity to coordinate quality control with laboratory testing, so that variations in testing can be properly segregated from real variations in quality.

Actual experience has shown that for some tests the variability of testing is fully as great as the variability of production. If, for a given test, sigma for a small, uniform test sample is no smaller than sigma for finished product over several months' time, then the test is not sensitive enough to reveal normal differences in quality of production; its only possible value is to detect gross variations. The test therefore supplies no valid information about product quality and may lead to complete confusion if interpreted without this knowledge. Sometimes specification limits have been found to be considerably narrower than six times the standard deviation of testing, as a result of which the product is often found to be off-specification merely because of the variability found in testing and irrespective of actual quality.

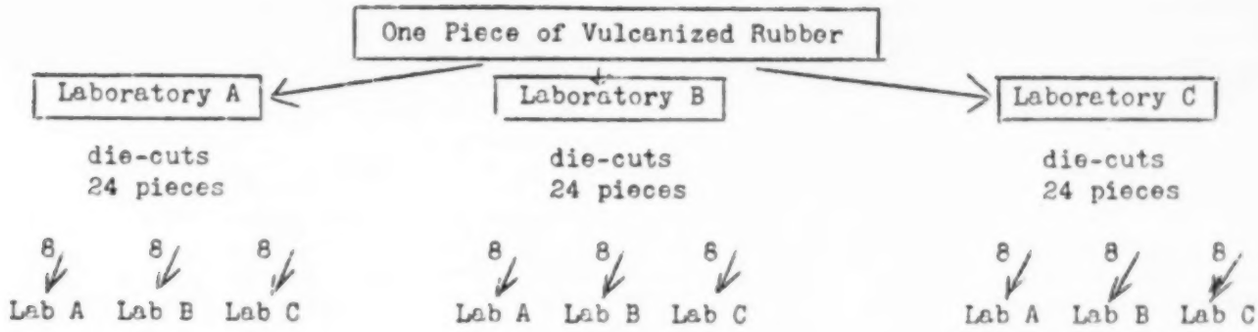
To combat these conditions, the synthetic rubber industry embarked on an exhaustive program of testing and cross-testing. It was axiomatic that if the finished product was to be uniform from one plant to the next and from one month to the next, testing must likewise be uniform from plant to plant and from month to month.

The cornerstone of the testing program was the use of standard samples. A portion of a large, uniform lot of GR-S was distributed to each producer, with the goal of having each laboratory obtain the same average results on this standard lot for every test. The same procedure was followed for important raw materials and intermediates. Whenever a batch of production samples was tested, a standard sample was also tested. The results were recorded on control charts in the following manner. On the bottom of the graph sheet were plotted the results obtained for the standard sample. Included in this control chart was a line in a different color indicating the "true" value for the standard sample (usually the results obtained by the Bureau of Standards were accepted as the "true" value). Thus one could observe from the chart whether testing was in control, whether there were any slow or cyclic trends, whether the average value corresponded to the "true" value, and, by the narrowness of the limit lines, whether precision was improving or deteriorating. On the same graph sheet, above the chart for testing, were plotted the charts for the product. Usually a separate chart was plotted for each independent manufacturing unit. Whenever the tests on the finished product indicated a slow trend, or a lot out of control, reference was made to the chart of the standard sample. If the latter showed similar trends, then testing was suspected. Or if testing appeared to be in good order, then the responsibility was placed on production. A set of charts such as described above is illustrated in Figure 2.

Note that during the first week in February the points on all the charts showed a strong upward trend, then returned to normal. The fact that the standard sample showed the same pattern indicated that testing must have been at fault. The actual circumstances were as follows: The temperature of the vulcanizing press (which vulcanizes the standard and the production samples simultaneously) was found to be too low, and the steam pressure was raised slightly so as to increase the vulcanization temperature. Actually, however, the method of measuring press temperature (by thermocouple pads and an insufficiently sensitive potentiometer) was not very accurate, as shown by later studies, and it was not the press temperature which had changed but rather the thermometric system. The next day the press temperature was still apparently too low, and again the steam pressure was increased. This continued for a few days until it was obvious that something was wrong with the thermometric system, and the steam pressure was reduced by stages until modulus values were normal. Thus modulus values were a more reliable "thermometer" than the thermocouple system. The Bureau of Standards later developed an accurate thermometric system for measuring press temperatures.

While these charts proved to be of inestimable value, it is obvious that they could not of themselves create any improvements or correct any consistent errors. Once the errors had been uncovered, it was necessary to find means of correcting unsatisfactory techniques, or of devising better equipment or more accurate procedures. As an aid to this program it was found that cross-testing between different laboratories provided a great deal of useful information. These tests were designed and analyzed by statistical methods so as to provide quantitative measures of testing variability (the standard deviation) and the significance of differences in average values. Often complex tests were broken down into several steps, and cross-tests run for each step, so as to help track down elusive sources of variability.

Sometimes an investigation of one particular step led to important information about other steps, as shown in the following example. Rubber samples, when tested for tensile strength and modulus (a measure of the degree of vulcanization) must first be compounded with various ingredients such as sulfur, accelerator, reinforcing agents, and other materials. The compounded material must then be vulcanized into thin sheets, and from these sheets dumbbell shaped pieces are cut out by means of a die. The dumbbells are then pulled apart on a tensile tester. It was believed that the condition of the die used might have a large effect on the values obtained for tensile strength and modulus, and so a cross-test program was inaugurated to check this point. Pieces of the same vulcanized sheet were sent to all participating laboratories to be die-cut and tested. To eliminate any variation due to the tensile operation, several of the dumbbell pieces were redistributed



RE-DISTRIBUTION DIAGRAM

to each laboratory in accordance with the scheme shown in the diagram on this page. Each laboratory measured tensile strength and modulus of the cut pieces.

When the results of the test were analyzed it was found that there was a considerable inconsistency which could not be explained except by assuming that the tensile strength and modulus were significantly affected by the time interval from the time of vulcanization to the time of testing. A further investigation confirmed this hypothesis conclusively, and as a result one other factor in the testing operation —time intervals—was standardized for more precise results.

The test further showed some variation between the different dies used, which was shortly traced to slight variations in the width of the die.

Analyzing Factory Data

Even extensive use of control charts cannot solve all of the factory's quality problems, as, indeed, would hardly be expected. But a surprising amount of useful and important information can be extracted by subjecting factory data to further statistical treatment, and this information may be utilized toward improving still further the control of product quality.

If data obtained in the operation of a plant are reasonably well kept, there is probably a mass of accumulated figures in the files covering many details of the process. These figures have no particular meaning unless they are properly organized and manipulated to yield such statistical results as averages, standard deviations, and correlation coefficients.

There are many changes in operation which have so slight an effect that they are undetectable by usual measurement. But when a great number of results are averaged, then even very small differences may be significant. Two slightly different units, running side by side and performing the same type of job, may have identical performance, as judged by a handful of figures. But when 500 figures are averaged, it may be found that one unit is significantly more economical than the other. Or when standard deviations are measured, one unit may be found to be significantly more uniform in behavior than the other. Such information can lead to steps which will improve the uniformity of the product or lower costs.

Correlation has been found to be of utmost value in analyzing factory data. Even very low correlations, unrecognizable except by a significant value of the correlation coefficient, may point to hidden or unsuspected relationships which may reveal why certain quality characteristics vary too much or what effect one characteristic may have upon another. For example, data on all of the specification tests were correlated with each other for several hundred different lots of GR-S. The results indicated that certain characteristics, though comparatively unimportant, had a considerable influence on a property known to be very important. As a result, it was found desirable to exert closer control on the former characteristics so as to improve the uniformity of the important property. These same **specification** properties were correlated with various **operational** variables, such as polymerization time, temperature, yield, viscosity, pH, and many others. From the results it was possible to ascertain the exact effects of operational variables on product quality, and judge therefrom which operations required the strictest control.

Very often results are obtained which indicate completely unexpected relationships; or it may be found that two different tests correlate very highly and therefore really measure the same property; or conversely, two tests thought to measure the same characteristic show no correlation and are thereby proved to measure different characteristics.

At one time during the latter part of the war there was a possibility of a sudden demand for a type of GR-S synthetic rubber with improved resistance to tearing. Some data on tear resistance were available on roughly fifty lots of GR-S. It was a simple matter to correlate tear resistance with all other properties measured, and it was found that one particular property—viscosity—showed a high negative correlation with tear resistance. If the demand for this type of GR-S had materialized, it would have been a fairly simple matter to have lowered the viscosity so as to improve the tear resistance.

Another example concerns the solubility of GR-S in benzene. It was found that some lots were completely soluble, while others had a small proportion of insoluble fraction. By correlating benzene solubility with all other measured properties, it was found that a significant correlation was obtained between benzene solubility and ease of processing. This finding formed the direct basis of further research which led, within a short time, to the development of a new, easy-processing GR-S, a product which is enjoying at the present time a wide demand for certain applications.

Control Charts for Management

A problem with which probably every executive is confronted is that of keeping well informed of what goes on without being swamped by a mass of detailed reports and by hundreds of figures which pass across his desk. While graphical presentation of data has been known and utilized by management for many years, modern control charts and distribution curves offer many additional advantages.

In various synthetic rubber plants, control charts have been posted in the control rooms, foremen's offices, and to some extent in the office of the production superintendent. In the daily tour of the plant, it is possible, by even casually inspecting the charts, to obtain quite a complete picture of plant operations. Especially important is the fact that **trends** are immediately apparent; whether the number of points out of control is decreasing or increasing; whether steam consumption is going up or down; whether the new control instrument installed on a certain reaction vessel has resulted in better operation; whether the difficulty the laboratory had been having with a revised method has now been straightened out.

Control charts have formed a basis for discussion at staff meetings, and have helped segregate responsibility for off-specification or out-of-control production on production, engineering, or laboratory.

Higher levels of management, too, have appreciated the conciseness and clarity of information provided in control charts and distribution curves.

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VI: Quality Control in Raw Materials Acceptance and Chemical Specifications

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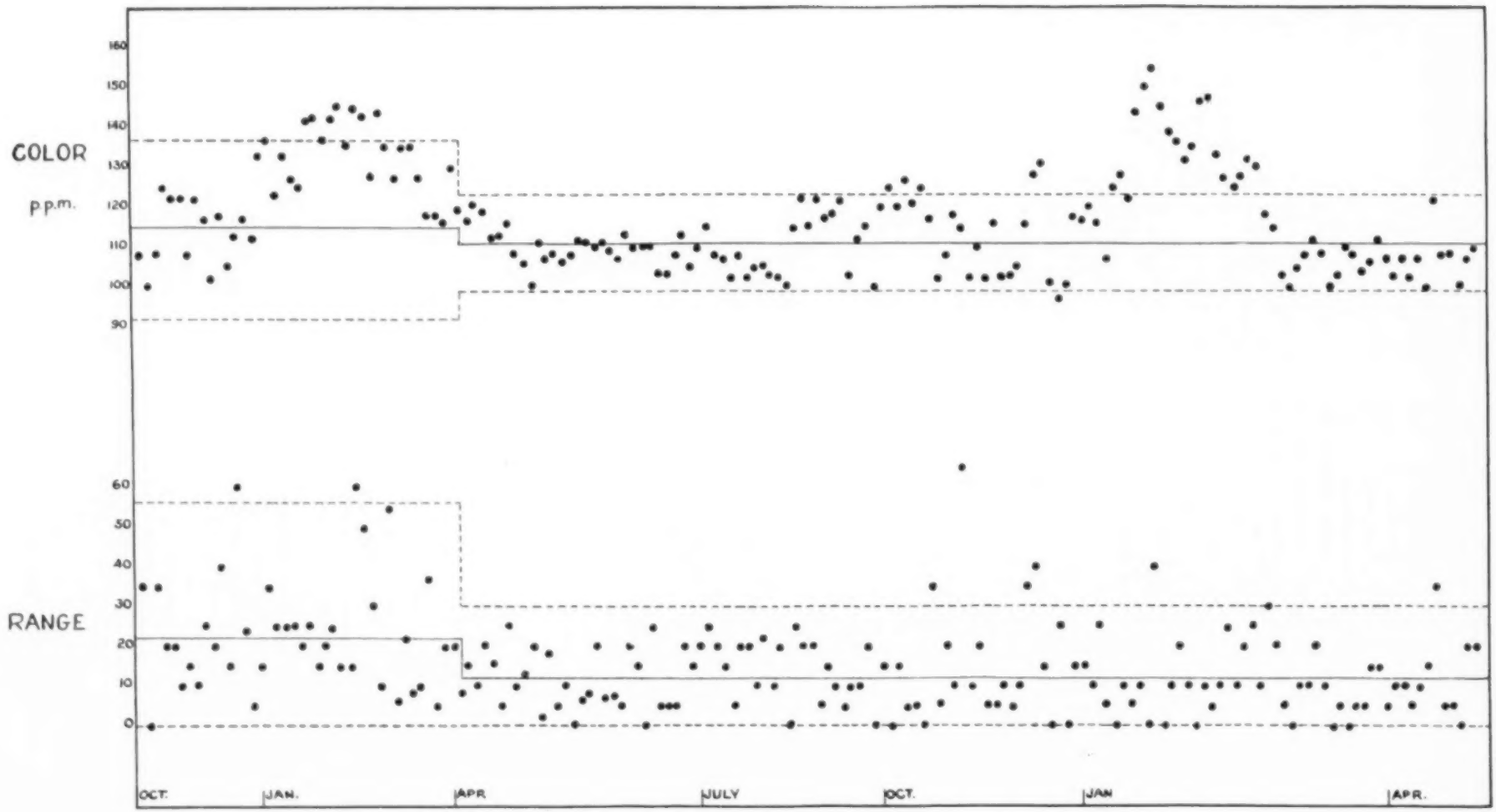
Part A: Acceptance of Raw Materials

In the chemical industry, the quality of the raw materials used is one of the most important factors in determining the quality of the final product. Each characteristic of the raw material is related in varying degree to some characteristic of the final product. The quality of the raw material also affects the cost, efficiency, capacity, and safety of the production process. In any efficient chemical process it is absolutely necessary to maintain an accurate control of the quality of the incoming raw material.

We have found that statistical quality control methods are a most efficient tool in the control of raw materials. By these methods it is possible to detect quickly changes in the quality of the incoming raw materials. Competitive materials can be accurately compared. The quality charts serve as an incentive for the supplier to improve his quality and provide a means for recognition of quality improvement. By cooperation with the supplier of the raw material, improvement in quality can be obtained and assignable causes of variation eliminated.

In starting the quality control of raw materials, it is best to start with some materials suspected to be the cause of some manufacturing difficulty, but do not start with a raw material with a very difficult problem. The following general program is given as a guide in tackling the problem. However, different types of chemical raw materials will suggest some variation in this approach.

1. Divide the supply of the raw material into definite units.
   In chemical raw materials these units are often easily identified as tank car, batch, cook, or some other unit of production.
2. Decide which raw material characteristics to control.
   Control the characteristics which have a definite relationship with final product quality or process efficiency and which show significant variation.
3. Make a control chart on these characteristics.
   Collect data from the inspection laboratories on each of these characteristics for each raw material unit. Group these units into convenient sub-



CONTROL CHART FOR COLOR IN CHEMICAL RAW MATERIAL

This chart shows the history of one quality characteristic of a chemical raw material. The original control limits were set up based upon earlier experience. It will be noticed that soon after the start of the chart signs of lack of control were detected. These signs were reported to the manufacturer and a correction of the difficulty was effected. This elimination of some cause of trouble produced consistently better results so that narrower control limits were adopted based upon the experience of the next month. Signs of lack of control were again observed a few months later. The condition was again reported and corrected after a period of investigation. Notice how far in advance of serious trouble the control chart warned of impending trouble. Note also the very definite shift in level on the color chart for the last two months shown.

groups in the order in which the material was produced.

4. Determine if characteristics are in a state of control.
   If signs of lack of control are detected, the quality of the material should be considered unreliable. It may, however, be advisable to continue the chart for a longer period of time before reporting this condition to the manufacturer. Lack of control of the quality of a raw material is a potential source of trouble in the process and should be watched very carefully. A large amount of sampling and testing is usually necessary to protect the process. On the other hand, a raw material which is found to be in a state of control may be judged to be reliable. The future variations can be predicted within limits. After a period of continued control, it is often possible to reduce the amount of sampling and testing.
5. Compare individual limits with the raw material specification.
   If the raw material quality is in control and three-sigma limits for individual lots fall within the specifications or requirement of the material, the raw material is satisfactory, and reduced sampling and testing can be introduced. If the raw material quality is in control but the limits for individual batches fall outside of the specifications, then contact should be made with the supplier to obtain a change in his operating controls or to reduce his process variation. In cases where no change in the quality of the raw material can be obtained, it is only realistic to change the specifications to conform to available supplies and to modify your process to accommodate such materials.
6. Report first sign of definite lack of control to producer.
   At the first sign of lack of control, return to complete sampling, if reduced sampling has been adopted. Carefully check sampling and testing procedure before making first complaint to producer. It is usually best to wait for a point definitely out of control (and also out of specification) before making first contact with producer. Supply the producer with all pertinent information.
7. When the condition is corrected, congratulate the producer and explain your system of inspection and quality control.
   Explain how your plan can work to mutual benefit.
8. When the next point out of control is found, report to the producer at once.
   It may be desirable to use the telephone. Explain that the condition may not be serious, but act quickly. Ask the producer to let you know if he succeeds in finding a cause of the trouble.
9. Continue to report any signs of lack of control.
10. After any period of consistent improvement, recompute the control limits.

The greatest difficulty in improving the quality of raw materials is the distance between the supplier and the user and the time required for quality information to be returned to the producer. It often happens that large quantities of sub-standard material are made by the raw material supplier before the user of the raw materials detects it. The control chart will reveal changes in raw materials in the most rapid manner possible and will often show difficulties before they have reached sufficient magnitude to affect the production process. However, control at a point remote from the scene of manufacture can not be completely satisfactory. The best solution to the problem lies in encouraging the manufacturer of raw materials to introduce his own system of quality control. When a raw material supplier does this, the quality assurance of his production is greatly improved and its value increased. In the chemical industry nearly every producer is the supplier of raw materials to some other industry, and the adoption of efficient quality control methods will aid in realizing increased value for the products of the entire chemical industry.

Part B: Chemical Specifications

Specifications have an important role in quality control in the chemical industry. They are concerned with the selection of raw materials, the inspection of the product in process, and the inspection of the final product. A specification is a written statement defining the standard of quality of a thing required for a certain purpose. It is a very important industrial tool because it can bring about that "meeting of the minds" of different people in different positions on quality. By means of an efficient specification, a testing or inspection department can routinely determine the suitability of any unit for the purpose for which the specification is designed. This is exceedingly important in large industries where men of experience cannot spend their time examining all products and raw materials. A well designed specification is a profitable tool; an inefficient one can be a liability.

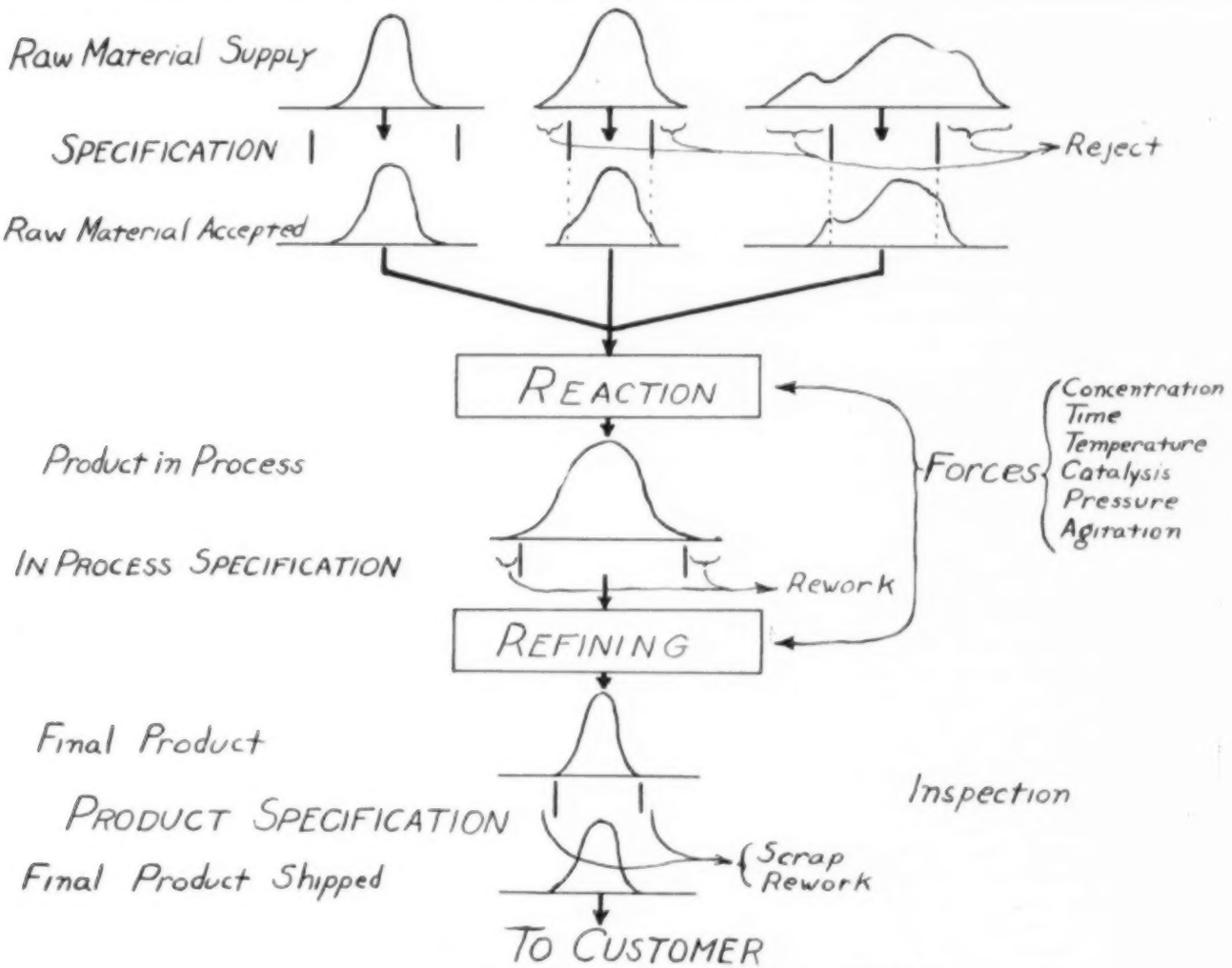
In order to create a chemical specification which will define quality, the following fundamentals must be observed:

1. We must select for measurement all the characteristics of the article which are known to be of importance to control for the purpose intended.
2. We must define a method of measuring each characteristic which is precise enough for the purpose and which is related to the quality characteristic under consideration.
3. We must choose a standard of quality which truly represents the best balance between the quality requirements of the consumer and the quality capabilities of the production process.

All too frequently chemical specifications have been established arbitrarily or from past precedent instead of by a scientific method. If a specification is going to do its

important job, it must be made for that job, and its creation will require as careful design and workmanship as the development of the process itself. In some cases it is necessary to make arbitrary decisions, but the chemist or chemical engineer who is setting a specification should use his knowledge of chemistry and production operations coupled with his understanding of the statistical nature of materials, men, and machines.

The quality control engineer should learn how to set specifications which are complete and which actually fix the quality definition, but are practical, realistic and possible of profitable fulfillment. They should provide the required assurance to the user and fairness to the supplier.



THE ROLE OF SPECIFICATIONS IN THE CHEMICAL INDUSTRY

This drawing shows the statistical nature of the variables in a simple chemical process and the controlling influence of specifications. The process illustrated is one in which several raw materials are mixed and reacted producing an intermediate product which is then refined to the finished product. Three distribution curves at the top represent different variations in some of the characteristics of the raw materials. The raw material specifications are illustrated by the dividing lines below the distribution. Their function is to pass material between the lines and reject material beyond these limits. The success of the specification depends on the precison of the sampling and tests specified. The type of distribution of the material accepted is illustrated below the specification limits. At the end of the reaction the variation in material produced is illustrated in comparison with an in-process specification which will attempt to limit the variation at this point. The final step of refining will reduce the variation in some of the characteristics and should produce a product within the limits of the final product specification. In these ways the specification is an integral part of the design and control of the process, and the successful operation of the process will depend to a great extent on the care and skill used in designing the specifications.

In establishing a specification for a chemical raw material, all the characteristics, chemical and physical, should be considered, and those selected which are known by chemical theory, production history, or correlation analysis to have a significant effect upon final product quality, process efficiency, safety, or cost. This list may be reduced by eliminating those characteristics which do not vary significantly in comparison with the requirements. Correlation analysis and variance analysis are two scientific methods for choosing those characteristics of importance. Control charts will accurately measure the variation and reliability of any characteristic.

The chemist should also make a study of the accuracy, precision, and reliability of any method given to measure each characteristic. He should make sure that the test method is precise enough for the purpose required.

The standard of quality should be selected to establish the best economic balance between the costs of the raw material, the costs of manufacture, and the value of the finished product. When a final product specification has been fixed by the consumer, the raw material standards and the process methods must be designed to fulfill the consumer's requirements. The process must be designed to produce the required final product quality from the available raw materials. In this case the process design engineer must make a balance between the quality of the raw material and the method of the process to produce the desired final product. The engineer should consider the economic effect and feasibility of using lower raw material quality with improved process methods or conversely of using simplified process methods and improved raw material quality. In any event the engineer must work within the range of available raw materials.

In-process specifications are determined in the same general way. Their purpose is to fix the quality and variation of the in-process material at some point during manufacture at which it is profitable and desirable to make an inspection of the in-process material. The relative economic advantages of passing or rejecting or reworking widely varying material at this point in the process should be considered. The limits should not allow any material to pass which is beyond the ability of the remainder of the process to bring within specifications. Statistical studies form the basis of the scientific selection of in-process specifications.

The final product specifications for chemical materials are usually determined by the consumer since the chemical material is frequently the raw material for another process or product. In this case the specification should be created by the consumer in accordance with previous considerations. The job of the supplier is to design a process to meet these specifications or to determine if his present process will meet its specifications. In other cases final product specifications are set by the producer to meet a general demand for a given quality of a chemical material. Sometimes several grades of this material are specified to give the consumer a variety. In this case the economic balance between the cost of material and its value is made by the producer. In any case, the three fundamentals of a chemical specification must be observed, and the selection of the characteristics, the methods of measuring each characteristic, and the standards of quality should be based upon careful scientific and economic studies in which statistical methods are of important assistance.

To compare a production process with a product specification, the control chart is a most effective tool. After the control charts have been set up on the desired properties the following questions should be asked on each control chart:

1. Are the data within control?
   If a process is within control the future quality variations of the process can be predicted within limits with reasonable assurance. However, if lack of control is shown, no prediction of future quality can be made, and the remaining questions will not apply. If the process is not in control, then investigation of a trouble shooting nature should be undertaken to find and eliminate the causes of lack of control. All efforts should be directed to bringing the process into control before proceeding with questions two and three.
2. Is the quality average within specification?
   If the quality average is too high or too low it may be shifted by changing the process controls. Sometimes it is not known how to do this. In such cases this should be assigned as a problem to development or process improvement groups.
3. Is the range of variation within specification?
   If the three-sigma limits for individual values lie within the specification, then the process may be judged satisfactory. If the variation is too great, then an investigation should be conducted to narrow the limits on raw material specifications, process control, or methods of tests. This may require assistance from development and research groups.

One of the most important factors to be considered in the application of specifications to chemical products is the precision of the chemical tests and sampling used to measure quality. Unless the accuracy of each test method is comparable to the requirements of the process and the specification, then difficulties and confusion will result. Under these conditions it is sometimes possible to substitute tests or, perhaps, to measure another factor which correlates with the property in question. The control chart and the correlation tests are excellent methods of doing this.

The chemical specification can be one of the most important methods used by the chemical engineer in process control. It must, however, be used with an understanding of the factors in the chemical process and the statistical nature of materials and forces. It is hoped that this discusison will aid in starting a trend toward more useful chemical specifications.

An Introduction to Sampling*

JOSEPH MOVSHIN
WAGNER ELECTRIC CORPORATION

Sampling, like the well known guest speaker, has been around long enough to need no introduction. But, as in the introduction to the well known guest speaker, we are about to go into a recitation on the peculiarities of the individual. Perhaps this is because we realize that sampling today is a bigger and better thing than ever; something we should know more about, and can easily learn. This last assertion could not have been made a few years ago. Simple techniques to provide the solution to complex problems of sampling probabilities were not available. Except to a few more mathematically minded than most of us, sampling was little more than a guessing game. Just plain, practical experience, however, did succeed in developing some pretty good guessers!

As a result of industry's great need for better sampling methods, a rapid development of theory took place before the war. During the war the application of this theory was thoroughly tested and expanded. Today, sampling plans based on accepted theory and proven practices are available to us. We have only to understand our own problem and look up the solution. It is a lack of understanding of the elements involved in a sampling problem that results in the failure of most sampling plan applications. Perhaps then, a review of the factors that must be considered in the selection and application of a sampling plan is in order.

Why is sampling so vital in modern industry's constant efforts to produce more and better goods at lower cost? Incoming material, the results of various phases of manufacturing processes, and the products offered the public are all repeatedly sampled. We must know that the elements that go into our plants are economically the best for our processes. We must know that throughout our shops we are utilizing raw materials, equipment, and labor as efficiently as possible. Lastly, we must deliver to the customer a product as good or better than our competitor's. Quality is always a factor in competition.

In industry, therefore, we find all sorts of people using all sorts of sampling schemes to sample all sorts of items.

Exactly what are they all doing? What is sampling?

Sampling may be described as a process for estimating some measurable function of the quality of a certain quantity of an item by an examination of a portion of the quantity in question. We might be interested in the variation of a particular critical physical measurement, or merely in the percent failing to conform to certain limits, that is, the fraction defective. We sample because we wish to estimate this information as economically as possible, and to base decisions for action on sample evidence. To inspect all of everything, even in a small shop, is certainly a most expensive undertaking; it is an impossible undertaking if the inspection test is destructive.

The word "economically" has appeared a great deal in our discussion up to this point. Sampling is an accepted practice because it is an economical way of obtaining very necessary information. Sampling, however, has been taken too much at face value. There is a great deal more to this business of sampling than has generally been recognized in our factories. Let us examine some sampling experiments and see what we discover.

Consider a box containing 2200 beads, some of which are red, or "defective;" the defectives we do not want. We take a random sample of 100. Suppose there are 7 defectives in this sample. What is the percentage of defective units in the lot? Can we say the lot is 7 percent defective? Let us take another sample. This time there may be 3 defectives, or 3 percent. If we take another sample we would probably get still another percent defective. What is the fraction defective of the lot?

We know, of course, that samples vary; everyone will agree to that! Yet it has been common practice when 10 defectives are found in a sample of 100 to say that the lot is 10% defective, and to proceed to act accordingly! But note that if we had said in our experiment that 5 percent defective was too great, and that we would reject the lot if 5 or more red beads were found in a sample of 100, we would have rejected the lot the first time, and when the same lot was offered again, we would have accepted it!

Some may say that they would not reject a lot on such limited evidence—they would resample it. Very well, but again the same lot could be rejected or accepted. Of course we could be sure of lot quality by inspecting the entire lot, and we do just that many itmes because we have to be sure. 100% inspection is still expensive, however, and is not necessary if all we want is a criterion for making consistent decisisons to accept or reject a submitted lot.

At this point the mathematicians can help us.

We can see that in a sample of size n from a lot containing n or more defectives, we can, theoretically at least, expect from zero to n defectives in the sample. We must assume that the lot is large enough, relative to sample size, so that the sample does not significantly change the percent defective in the lot.

To have sampling do for us exactly what we wish it to do, we

*A talk presented to the St. Louis Section, ASQC—December, 1946.

must understand the nature of the probabilities involved in finding a specific number, c, of defectives in a sample of size n from a lot with a fraction defective or percent defective, p. The probability of c defectives in a sample of size n, from a lot with fraction defective p, is the same as the probability of acceptance of a lot of this percent defective, using c as the acceptance number of defectives in a sample of size n. How does this work in a sampling plan?

A fairly common practice is to specify some fixed percentage of the lot as the sample and an acceptance number of zero. We shall specify 10 percent of the lot as our sample, and reject the lot if any defectives are found.

Suppose our supplier has a fairly good, uniform process averaging about 5% defective, and that material of this quality is acceptable for our purposes. The items arrive in various sized lots running from about 100 or so to shipments of 1000; not too uncommon a situation. Now let us see exactly what our plan does.

For a lot of 100 our sample size is 10. The probability of 0 defectives in 10 from a lot 5% defective is about .6. This means that on the average we can expect to accept about 6 and reject about 4 out of every 10 lots of 100 pieces offered. If a lot of 200 arrives, our 10% sample of 20 with c = 0 would give the lot about a 37% chance of acceptance. We could now expect to accept a little less than 4 and reject a little more than 6, on the average, out of every 10 lots offered. When lots of 1000 arrive, the sample of 100 would lead to practically no acceptance of this same 5% defective material — about 7 out of every 1000 lots of this material would show no defectives in the 10% samples of 100 per lot.

"Well, all right, we'll let them have a couple of defectives in a sample of 100" is the usual reaction to the rejection of a lot of needed material. This would change the probability of acceptance to .125 — about 12 to 13 lots out of every 1000 lots submitted. But it is still the same material! We have thrown back by our strict 10%, c = 0, sampling plan 40% of all lots of 100, 60% of all lots of 200, and now we are led to think that practically no lot of 1000 is really good!

Suppliers who may have trouble understanding why we rejected some material that was the same as that accepted may be pardoned when they question our methods. Certainly they are entitled to an acceptance criterion showing more consistency than does the average inspection plan of the type we have just illustrated!

From our own viewpoint as buyers, are we content to accept half the lots of 100 offered that are 7% bad, while rejecting half the lots of 200 that are only 3.5% defective? That is what this 10% plan is doing!

A single sample size for various sized lots gives a much more consistent plan. Actual sample size is a far more important factor in the probabilities of sampling than is the ratio of sample size to lot size. This does not hold for very small lots, but is true in general. However, we still do not know how good an accepted lot really is, or how much good material is being returned in a rejected lot. No **sampling** plan will give this information for a **single** lot. But a **good** sampling plan will give good, **average**, over-all lot-quality protection for a **series** of submitted lots. It scarcely seems necessary to emphasize that it is expensive either to accept very much poor quality material or to reject very much usuable material. A really good sampling plan must perform consistently with respect to specified risks of making these two types of costly mistakes. We shall return to this problem later, but just now, let us illustrate further the importance of sample size.

Consider a deck of playing cards. Select a card. Suppose it is a queen. Is the deck a pinocle deck? Are all the cards nines or higher? They could be. We can't tell from one card. Take another card. Suppose it is a jack. We still do not know the nature of the deck. How many cards must we take with no card below a nine appearing to decide that the deck is not a regular deck? (Let's ignore the possibility of getting two cards identical as we could from a pinocle deck of 48 cards.) What are the probabilities of drawing 1, 2, 3, 4, 5 or more cards without getting one below a nine in a regular deck of 52 cards? Our mathematical friends again have the answer. If the cards as drawn are not replaced, the probability of

1 out of 1 being 9 or above is .462
2 out of 2 being 9 or above is .208
3 out of 3 being 9 or above is .092
4 out of 4 being 9 or above is .039
5 out of 5 being 9 or above is .016
6 out of 6 being 9 or above is .007
7 out of 7 being 9 or above is .003

If the results of an incorrect decision (i.e., deciding the deck is not regular when, in fact, it is) were not too costly, we might decide after 3 cards, and take about a 9 in 100 chance of being wrong. Should much more be at stake, perhaps 6 cards should be drawn, with a chance of about 1 in 100 of misjudging the deck.

Thus, sample size does, to a large extent, determine the ability of the sample to yield correct decisions — it determines the probability of misjudgment. With a larger sample size, we can more accurately estimate the average quality of the material in a series of submitted lots. By increasing sample size we can reduce the risks involved in sampling to whatever value we are willing to pay for in sampling costs.

Let us try some more sampling. Consider a **new**, regular deck of 52 cards. Suppose our sampler is a man from Mars where they don't have playing cards. He starts sampling: 1, 2, 3, 4, 5, 6 spades right off the top! It begins to look to our friend from Mars as though a deck of cards has one color and pattern, but different values. But we know that isn't so. We also know that the probability of 6 in a row, all of one suit, from a regular deck of cards is about .00034.

The explanation is, of course, obvious: the deck hasn't been shuffled, and we know that the four suits come arranged together in the assembly and packing of the deck. In our remarks on sampling and probabilities we have been making an assumption — the same one that underlies practically all sampling probability calculations: we assumed random sampling.

We all realize that a sample should contain elements from all possible groups that might be included in a lot, but the full mean-

ing and implications of this vital concept — that of a random sample — may have eluded us. "Take a random sample" the Dodge — Romig, Ordnance, Navy, and Quartermaster sampling guides order. They fail, however, to tell us how to do this. We must decide for ourselves for each lot of each item we wish to sample. We can try to follow the definition that a random sample is one for which every unit in the lot has an equal chance to be selected for the sample. Often, due to the physical features of size, packaging, or nature of the items, this cannot be done. Dr. Shewhart* asks, "How should we choose a random sample of the tensile strength of a coil of wire?" He gives no specific answer! At the Wagner Electric Corporation the following solution has been used: After discarding the damaged coil ends, a length of about 5 feet is taken at the beginning of each, roughly, 2-mile reel of wire for a stiffness test. With respect to a single reel of wire this may not be a random sample. However, if we consider that the wire arrives in carload lots, and that quite a large number of reels are used monthly, then a five-foot sample from each reel begins to assume the status of a fairly good approximation to a random sample.

Perhaps as good a general solution as any of how to take random samples lies in the idea of rational subgrouping.** This requires that the entire lot be divided into sections which may be expected to differ. Subgrouping may be done with respect to supplier, packaging, dates of shipment, machines, shifts, different sources of raw materials, batches, or any known distinguishing factor or circumstance in the history of the material. The sample is then taken partly from each of these sublots. The judgment of an experienced inspector is an excellent guide in many such cases. He will know where differences have occurred before, and so he can subdivide the lot in accordance with known probable sources of variation — he knows how the deck may be arranged! A sample, to represent the lot in accordance with the theory used, must contain individual units from all possible sections of the population. In the failure to apply this principle lies the failure of many otherwise good sampling plan applications.

At this point it may be desirable to mention an extremely valuable piece of simple advice: identify each portion of a sample with the lot subgroup from which it came. This can be done quite simply, and may very often save a great deal of later work and time.

The actual selection and application of a sampling plan is fortunately easier than our consideration of the basic problems might indicate. We have only to decide what we want the plan to do, and then pick a plan that most nearly meets our requirements from among the variety of plans that are available.

We first must specify certain constants for the plan. We have to know what is to be considered a "good" lot, and what a "bad" one. This is entirely an economic consideration to be governed only by the quality of materials we are willing to pay for. These two constants, the **Acceptable Quality Level** or good lot, and the **Lot Tolerance** or bad lot, have associated with them two probabilities. In the case of the Acceptable Quality Level, we must specify what **risk of rejection** of this good lot the plan shall have. We must also specify what percentage of Lot Tolerance material we are willing to have the plan give us.

These two values of quality, and their associated **Producer's Risk** of rejection of good lots, and **Consumer's Risk** of acceptance of bad lots, will define a plan for us. Frequently only Acceptable Quality Level or Lot Tolerance is listed as defining a plan. In these cases the missing elements are standardized for a group of plans. It may be a single, double, or sequential plan, as we wish, depending on the considerations. We may use Ordnance, Dodge-Romig, Navy, or Quartermaster tables, or make our own, and know what to expect. Associated with the plan will be an **Average Outgoing Quality Level** which will tell us the poorest average quality the plan will pass into stock, provided we detail (inspect 100%) each rejected lot, and replace all defective units found by good pieces. We could, in fact, select a plan to yield any specified Average Outgoing Quality desired.

Once we decide what we want the plan to do, the appropriate sampling table used will specify the correct sample size for the type of plan chosen. If too much sampling is called for, perhaps a different type plan may be better. Average Sample Number curves for the different type plans can be consulted to help us select the most economical one for our problem. Again, if the sample is too large, perhaps the quality we have specified is better than we really need, or else the risks are too low. We must expect to pay for requiring better quality and/or greater assurance by having to use larger sample sizes, taken, of course, with due regard to the requirements for a random sample. In certain circumstances, only 100% inspection can reduce the risks enough to guarantee the quality required.

There is little more that can be said in a general introduction of this nature. We have met sampling. We are aware of its peculiar behavior. Samples will vary from the same lot in accordance with the laws of probability. We know that sample size is a key factor in having sampling do the job for us as we wish. The basic necessity for random sampling is fairly obvious. The rest is all arranged for us. We specify our Acceptable Quality Level, with its Producer's Risk, and the Lot Tolerance with its Consumer's Risk. All we have left to do is to pick the type of plan we wish, and it will give us our sample size and acceptance values. If we prefer, we may select a plan to

*"Economic Control of Quality of Manufactured Product," page 408.

***Editorial Note:* Samples selected in this way do conform to Shewhart's definition of random sample (p. 406 of his book), but they are probably better known as "representative" or "stratified" samples. The author's discussion here simply underlines the very fundamental, common-sense fact that the method of selecting the sample must fit one's a priori knowledge of the universe being sampled. Thus, the first 6 cards off the top of a deck are just as "random" and "representative" as any other unbiased selection of 6 cards if one knows in advance that the deck has been thoroughly shuffled! M.E.W.

give our process some particular Average Outgoing Quality Level. Again, we merely decide what we wish, and look up a plan. Those who desire may even make up their own plans. Convenient data for this are also available.*

We cannot close, however, without a word on keeping records. Be they ever so simple, they are necessary, and extremely valuable. They tell us when we can afford to use reduced sampling; when a process is more efficient, or in need of aid; when trouble may be approaching; or how well inspectors are doing their job. We may want an elaborate control chart, or merely a check on a form. In any event, every time an inspector looks at an item we are buying information. We might just as well use it! In the utilization of daily inspection data lies the great power and utility of sampling and quality control.

Sampling, as an industrial tool, can be applied with great effectiveness in all our work. It has been made available to us in many simple but scientific forms of application. It comes packed, ready to use—satisfaction guaranteed when used as directed on the package!

*Dodge-Romig "Sampling Inspection Tables", p. 44. Also, "Sequential Analysis of Statistical Data: Applications", Columbia University Press, 1945.

Syracuse University and Syracuse Section of ASQC Open Quality Control Project

On Wednesday evening, October 8, Syracuse University, in cooperation with the Syracuse Section of ASQC, officially opened the government sponsored investigation and training project in statistical quality control at a management session attended by over 300 industrial executives and quality control engineers of the Syracuse area.

After introductory remarks by William P. Tolley, Chancellor of the University, and Roland Noel, Syracuse Chairman of the American Society for Quality Control, the conference was addressed by H. Paul Nelligan, President of the Easy Washing Machine Corporation, Ralph E. Wareham, Executive Secretary of ASQC, Simon Collier, Director of Quality for Johns-Manville Corporation, Dr. Martin Brumbaugh, Director of Statistics for Bristol Laboratories, and Edward A. Reynolds, who is in charge of the University's project.

The purpose of the conference was to give industrial management an over-all and non-technical explanation of the usefulness and techniques of statistical controls for the evaluation of developments, the improvement of quality, and the lowering of scrap and rework costs. The meeting was the first step in the project which has been allotted $19,600 by the Department of Commerce to investigate the use of statistical methods in this area and to aid local industries by training courses and in-plant cooperation in the installation of statistical controls.

Mr. Nelligan emphasized management's responsibility for considering the potential benefits inherent in statistical quality control. He pointed out that never before in American history has high productivity of acceptable merchandise and lowering of costs been more necessary than it is today, and that statistical techniques can aid management greatly in attaining these objectives. In his opinion, the old type pre-war inspection was entirely inadequate because it was based on after-the-fact sorting, whereas modern quality control aims at satisfactory design, establishment of proper production flow and methods, and control of the product from drafting board to shipping room, so that the manufacture of defective material and production bottlenecks can be prevented rather than patched up after they occur. He compared statistical quality control in a modern manufacturing organization with the C. I. C. in Naval terminology, since it served as the Center of Information and Control, and he illustrated his point with a chart showing quality control as the hub of the manufacturing wheel, coordinating and controlling the activities of design, production, personnel, and inspection. According to Mr. Nelligan, the full application of statistical quality control is something not yet realized by the majority of industries, even those who are using it in part. He felt its full possibilities were not known even yet; however, it has already been accepted by his company and by many others as one of management's most effective aids in the economic control of mass production.

Mr. Ralph E. Wareham outlined industrial progress through the use of statistical controls during the past decade, and pointed out the increasing use of these techniques since their origin by Dr. Walter A. Shewhart over twenty years ago. Mr. Wareham stated that to date, most of their applications have been for the control of mass production where large volumes of the same items were turned out. However, they can also be applied to control the production of small quantities of different items produced on similar equipment.

Mr. Simon Collier presented the 45 minute sound-color training film, "Modern Quality Control," originally designed to train engineers and executives of the Johns-Manville organization, but widely requested by technical societies and other industries for basic training in statistical techniques. Mr. Collier outlined a few of the many applications of statistical controls throughout his organization, especially on chemical and semi-chemical processes, and the efficient establishment and control of visual standards of appearance.

The efficient use of statistical quality control, emphasized by Mr. Collier, requires cooperation between all divisions of a manufacturing organization, including engineering, design, production, and sales departments. Without this cooperation, progress is limited, and as a result of the need for educating and selling all divisions of a company, initial results are necessarily slow. He stated, that in some cases, it has taken up to two years to apply statistical quality control satisfactorily to a particular product. He warned the group not to be discouraged at preliminary delays since, as further experience is obtained, success is more rapid, and eventually, the entire organization will be enthusiastically using these methods with success.

Dr. Martin Brumbaugh summed up the advantages of statistical techniques, and said that Syracuse has a unique opportunity to secure training and assistance through the University's project, which includes training classes and in-plant cooperative aid.

Mr. Edward A. Reynolds announced the opening of the University's free training classes on October 14 and invited all the companies represented to send men to take this basic training. He emphasized that the University's course which covers a total of 45 hours over a period of 18 weeks, would not produce finished quality control engineers. It was the University's plan to give sufficient training in the fundamentals in this period so that men with a high degree of knowledge of their own processes and an interest in the betterment of their product could apply statistical controls in their own plants.

Book Review

Peach, Paul, "An Introduction to Industrial Statistics and Quality Control," Edwards and Broughton Co., Raleigh, N. C., 1947, 235 pp. Review by Martin A. Brumbaugh, Bristol Laboratories.

This text is written for the quality control operator who needs a ready reference guide on his desk. It is written for the student who wants the essentials of practical control procedure supported by sufficient statistical background to answer the question, "Why?" This statistical background is woven into the quality control application so effectively that operators will not find the statistical development burdensome; likewise statisticians will not find the presentation of technique diffuse.

The general plan of the Chapters is to present acceptance sampling and the principles of probability first, then the usual control charts, followed by significance tests, special charts, and elementary analysis of variance. A set of twenty examples in Appendix A, a brief reading course in Appendix B, and a well chosen set of tables complete the content of the book.

The introduction to elementary principles of probability and the construction and use of probability distributions as presented in Chapter I leads naturally to acceptance sampling in Chapter II. Here the risks of sampling plans and the relation of producers' and consumers' risks to acceptable and unacceptable quality levels are presented along with a generally usable single sampling plan. One statement in this Chapter may become a subject for argument. To quote: " - - - the vendor should know what value of p_1 (acceptable quality level) has been set. This does not apply to p_2 (rejectable quality level); indeed, as a matter of policy, information about p_2 should never be given to an outsider." This reviewer is familiar with many cases in which the consumer has given his supplier full information concerning his acceptance plan; indeed, in many cases the supplier is encouraged to use the same inspection plan before shipping that the consumer uses in receiving inspection. Perhaps the point of view on this subject is directly related to the vendor-purchaser relations existing in a particular case.

Chapters III, IV and V contain the complete explanations of the principles, construction and interpretation of control charts. There are so many guides, special instructions, and auxilliary uses presented in these Chapters that it would not be feasible to list them, much less explain them. Although condensed into fifty pages, this core subject is completely and clearly presented.

The analysis of various double and multiple sampling plans in Chapter VI is excellent. An appraisal of various plans is there for the reader desiring to know which plan to use in a particular case. An explanation of procedure is there for the person who wishes to employ a particular plan in his plant.

Chapter VII dealing with significance tests is well done in general, but the sections explaining the meaning of significance tests and acceptance inspection by variables deserve special mention. Some special quality control methods are presented in Chapter VIII, but this Chapter is considerably less informative than Chapter IX, which presents ably (1) the method of setting specifications when several mating tolerances are involved, (2) gage tolerances, (3) the distinction between precision and accuracy of measurements, and (4) sources of error in measurements. Chapter X on variance analysis is intended to be introductory, and deals only with the elementary uses. The final Chapter XI contains the author's point of view regarding the organization form, type of personnel, and place in plant organization of a quality control department.

This book is written in the easy to read, easy to remember style for which the author is well known. The pithy comments thrown in at well chosen points act as catch phrases to fix in the reader's mind

important principles and conclusions. At no point is the presentation beset by excess verbiage; in a few places the presentation might be benefited by additional explanation. Certainly the preceding comment should not be interpreted as derogatory to a sound, interesting, elementary presentation of quality control principles and the background of statistical technique necessary to an understanding of these principles.

There are a few points to be mentioned on which there will not be universal agreement among readers:

1. At the bottom of page 63 it is suggested that $(1-\bar{p})$ may be ignored in the formula
$$n\bar{p} \pm 3\sqrt{n\bar{p}(1-\bar{p})}$$
so long as $\bar{p}$ does not exceed 20%.
2. On page 74 the factor $1/d_2$, ordinarily employed to estimate universe standard deviation from average sample range, is used to make this estimate from the range of a single sample of 5 items.
3. On page 124 a similar procedure is presented for estimating universe standard deviation from the standard deviation of a single sample using the factor $1/c_2$.

ADVANCE NOTICE

Second Annual Convention American Society for Quality Control

AND

Fourth Annual Quality Control Clinic Rochester Society for Quality Control

CHAMBER OF COMMERCE, ROCHESTER, NEW YORK
MONDAY AND TUESDAY, FEBRUARY 16 AND 17, 1948

The Executive Committee has accepted the invitation of the Rochester Section to hold the Second Convention of the American Society in conjunction with the Fourth Annual Quality Control Clinic of the Rochester Section in Rochester on February 16 and 17, 1948, as indicated above.

Those who attended the First Convention in Chicago in June, 1947, have been looking forward with anticipation to this announcement. Those who missed the first one now have an opportunity to make their plans amply in advance to permit taking advantage of the second. The reputation of the Rochester Clinics for unusually fine programs guarantees excellent clinical sessions.

A tentative program for the Convention has already been worked out. The first morning will be given over to registration, possible committee meetings, etc., and a time for members to greet each other. Clinical sessions will be held on the first afternoon, the second morning and the second afternoon. There will be general luncheon sessions on both days with top-rate quality control speakers. The dinner session on the first day will be the annual dinner meeting of the Rochester Clinic with a well-known industrial executive as a speaker. The dinner session on the second day will be the annual dinner meeting of the American Society. The outstanding success of this dinner meeting at the first Convention guarantees that members will not wish to miss it.

The working out of detailed plans for the Convention is going forward as rapidly as possible, and members will be notified of them as they are completed. A complete program will be included in the January issue of Industrial Quality Control. Responsibility for the detailed plans in the first instance rests with the usual committees of the Rochester Section, and they will receive such help and cooperation as possible from the other five Sections in the Northern Region and from the General Committees of the American Society.

In the meantime, members will wish to make note of the dates in planning their schedule. Inquiries regarding the Convention may be addressed for the present to:

Mr. L. E. Coger, Secretary
Rochester Society for Quality Control
c/o Rochester Products Division
General Motors Corporation
1000 Lexington Avenue
Rochester, N. Y.

or to:

Mr. R. E. Wareham, Executive Secretary
American Society for Quality Control
305 East 43rd Street
New York 17, N. Y.

All inquiries regarding exhibit space at the convention should be addressed to Mr. Coger in Rochester.

Information regarding hotel reservations, etc., will be forthcoming shortly.

AMERICAN SOCIETY NEWS

BOARD OF DIRECTORS 1947-48

New Directors having been duly chosen to succeed all of those whose terms have expired or who have resigned, the Board of Directors for 1947-48 is now complete and is constituted as follows:

Chairman

George D. Edwards, President
Frederick J. Halton, Jr., Vice-President

Secretary

Ralph E. Wareham, Executive Secretary

Directors

Alfred L. Davis, Treasurer
Mason E. Wescott, Chairman, Editorial Board
B. B. Day, Baltimore
Warren R. Purcell, Boston
Alfred J. Winterhalter, Buffalo
Wyatt H. Lewis, California
Ernest H. Robinson, Chicago
Wayne A. Kirklin, Delaware
Ralph A. Hefner, Georgia
Stanley G. Johnson, Hartford
A. C. Richmond, Illinois
Arthur Bender, Jr., Indiana
James M. Ballowe, Iowa
Paul S. Olmstead, Metropolitan
Herbert G. Winter, Michigan
Bernard F. Litzau, Milwaukee
Keith E. Ross, North Eastern Indiana
Carl W. Helmstadter, Omaha
Wade R. Weaver, Ohio
Irwin S. Hoffer, Philadelphia
H. L. Springer, Pittsburgh
Halsey H. Kent, Rochester
Lester S. Kauffman, St. Louis
Elwood E. Folsom, Jr., Southern Connecticut
Merlin J. Barret, Southern Tier
Martin A. Brumbaugh, Syracuse
B. A. Griffith, Toronto
Edwin R. Salzer, Washington
Joseph J. Ferri, Western Massachusetts

EXECUTIVE COMMITTEE MEETS

The Executive Committee held a highly successful two-day meeting at the Homestead of International Business Machines Corporation in Endicott, New York on 13-14 September. All but two of the eleven members of the Committee were present.

The Executive Secretary reported total membership of 2,088, of whom 92 were Senior Members. It was agreed that each Regional Director is to follow the Directors in his Region and to report at the next meeting what steps are being taken for each Section to secure: (a) the highest possible percentage of membership renewals; and (b) the highest possible ratio of Senior Members to total.

The Treasurer presented a report showing a balance of $3,046.04 on hand as of 8 September, 1947. A tentative budget of $13,900 for the year 1947-48 was adopted. It was agreed that each Regional Director is to follow the Directors in his Region and to report at the next meeting what steps are being taken by Sections in his Region toward bringing their fiscal years into conformance with that of the American Society as required by the new Constitution. Routines for approval of bills for payment by the Treasurer, were approved by the Committee.

The President submitted his nominations for the several Standing and Other Committees for 1947-48, and these were duly approved.

The Executive Secretary was directed to forward to each corporate member of the Society a return post-card questionnaire in order to obtain full information necessary for publication of the next Year Book.

Each Regional Director agreed to follow the Directors in his Region on the matter of insuring that all Section nominees to American Society General Committees are corporate members of the American Society as required by the Constitution. Similar follow-up is to be made with respect to Section Officers, since these can be listed in the Year Book only to the extent that they are corporate members of the American Society.

There was substantial discusison of the question of profesisonal ethics as involved in Society publications and in the conduct of the individual member. Numerous other matters were given detailed consideration, and action taken in connection with a number of them is recorded elsewhere in this issue of the magazine.

★

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BALTIMORE AND WASHINGTON SECTIONS RECOGNIZED

During the Spring and Summer of 1947, active effort on the part of a number of energetic American Society members in the Baltimore and Washington areas resulted in organization of local groups, both of which applied for recognition as Sections of the American Society.

Such recognition was voted unanimously at the Executive Committee meeting in September, so that the American Society now has twenty-seven active Sections. Mr. A. J. Duncan is Chairman of the new Baltimore Section, and Dr. William R. Pabst, Jr., is Chairman of the Washington Section.

ACTIVATION OF FELLOW GRADE OF MEMBERSHIP

At the meeting of the Executive Committee in Endicott on 13 September, 1947, the following steps were taken to implement the provisions of the new Constitution with regard to the Fellow grade of membership in the Society:

1. With the approval of the Executive Committee, the President duly appointed those members of the Executive Committee present to act temporarily as the Examining Committee;

2. The President then submitted to the Examining Committee the names of the following corporate members of the Society for transfer to the grade of Fellow:

Dr. Martin A. Brumbaugh,
Mr. Charles J. Hudson,
Dr. Lloyd A. Knowler,
Dr. Paul S. Olmstead,
Dr. Walter A. Shewhart;

3. The Examining Committee unanimously approved all of the above transfers;

4. The members of the Examining Committee thereupon resigned their duties in that capacity and reconvened as the Executive Committee;

5. The President then submitted to the Executive Committee proposed appointment of the five Fellows created above to serve as the Examining Committee, with Dr. Olmstead as their Chairman;

6. The Executive Committee unanimously approved appointment of the Examining Committee as proposed above.

There was thus born within the Society a self-perpetuating Fellowship of maturity and experience, which is open to all corporate members of the Society having the requisite qualifications set forth in the Constitution. It is expected that this group of Fellows will exercise a continuing influence, which will contribute materially in helping the American Society to maintain for itself a character of conservatism and maturity.

The new Examining Committee is already hard at work on its rules of procedure and on the drafting of an application blank for transfer to the Fellow grade. It hopes to have this blank in the hands of Section secretaries by early December for distribution to those members of the Society who are interested.

Letters have been received by the Executive Secretary from a number of members requesting transfer to the Fellow grade. As soon as transfer application blanks are available, the Executive Secretary will forward them to the writers of such letters, to be filled out and returned for consideration by the Examining Committee. In the meantime, it will unfortunately be necessary for the Treasurer to return any dues amounts forwarded by members in excess of those required for the Senior Member grade.

MEMBERS-IN-TRAINING

The Constitution permits the Board of Directors to "provide in the By Laws for the enrollment of Members-In-Training" in the American Society for Quality Control. At its September meeting, the Executive Committee referred to the Constitution and By Laws Committee the matter of drafting a suitable By-Law covering this matter.

In the meantime, the Executive Committee voted to permit immediate enrollment as Members-in-Training of "bona fide full-time undergraduates in accredited educational institutions of college grade." Dues for Members-In-Training, as established by the Constitution, are to be $3.00 per year. These include subscription to Industrial Quality Control. Under the Constitution, Members-In-Training are not "deemed to be corporate members of the Society," and they hence have no vote.

Special application blanks for the enrollment of Members-In-Training are in preparation. In the meantime, Section Secretaries may accept applications, with $3.00 dues, on the present blanks. Such applications must state: the name of the educational institution in which the applicant is enrolled; the fact that he is enrolled as a full-time undergraduate; the degree for which he is a candidate, and the year in which he expects to receive his degree. Enrollment and dues will cover the period until 30 June, 1948, and will include back issues of Industrial Quality Control beginning with July, 1947.

MEMBERSHIP RENEWALS AND NEW MEMBERS FOR 1947-48

As of 28 October, 481 of the 1946-47 members of the Society had paid dues for 1947-48. This represents just 25% of the 1946-47 membership. It is recognized that, at that time, a number of the Sections had only recently gotten out their bills, and it is hoped that a loyal response to these will result in a material improvement in the Executive Secretary's next report on the status of the membership roll.

Sectionwise, renewals were extremely spotty. Iowa, Buffalo, Georgia, Ohio, and Western Massachusetts, in the order mentioned, had re-enrolled 50% or more of their 1946-47 membership, — Iowa topping the list with 57%. Four Sections had re-enrolled no members as of the date mentioned, and three others had enrolled less than 10% of their 1946-47 members. It is hence obvious that some of the Sections need to do some real work on this matter.

The situation with respect to new members is much more encouraging. As of 28 October, 296 members not previously identified with the Society had paid dues for 1947-48. Two new members were thus joining the Society for each three renewals, and it is hoped that this

gratifying showing will continue. Here again however, the situation is extremely spotty.

Two Sections, Western Massachusetts and Ohio, are to be congratulated on already having more paid-up members for 1947-48 than they had for 1946-47, — Western Massachusetts with 144% of its 1946-47 membership, and Ohio with 102%. Two Sections show no 1947-48 members whatever, and two others show a paid-up membership for 1947-48 less than 10% of that for 1946-47. As of the date mentioned, total American Society paid-up membership for 1947-48 stood at 777, or 40% of the 1946-47 figure.

TRANSFERS TO SENIOR MEMBERSHIP

As of 28 October, 266 of the 481 1946-47 American Society members who had paid their 1947-48 dues had transferred to the Senior Member grade. As with renewals, the showing of the various Sections is also very spotty in this matter. Seven of the Sections show 100% of their renewals as transfers, but only three of these had sufficient renewals to be significant. At the top of the list is Philadelphia with 25 renewals and 25 transfers. Georgia follows with 10 renewals and 10 transfers, and then Western Massachusetts with 9 renewals and 9 transfers. Iowa and Ohio, both of which have staged real campaigns for Senior Membership, continue in the lead so far as numbers are concerned, — Iowa with 50 renewals and 49 transfers, and Ohio with 50 renewals and 46 transfers. The five Sections mentioned have definitely proved that the goal of the Society is attainable if the necessary effort is put forth, and it is hoped that all of the other Sections will follow their fine example.

ADVERTISING IN INDUSTRIAL QUALITY CONTROL

At its meeting in Endicott on 13 September, 1947, the Executive Committee approved the President's appointment of Mr. Edward D. Thompson of the Chicago Section to be in charge of securing advertising for Industrial Quality Control and for the Supplement. This appointment is with the understanding that Mr. Thompson is to be considered Chairman of a one-man Committee on Advertising, to which he is free to add members of his own choosing if and as he may find this of advantage. The Society is most fortunate in having received Mr. Thompson's acceptance of this responsibility, and is most grateful to him.

Inquiries concerning advertising rates, contracts, and space available in either Industrial Quality Control or the Supplement, should be addressed hereafter to

Mr. Edward D. Thompson
American Society for
Quality Control
Post Office Box 1097
Chicago 90, Illinois

STANDARDS COMMITTEE ACTIVATED

With the appointment of the Committee on Standards, the Society has activated its first Technical Committee. Personnel of the Committee is as follows:

Committee on Standards:
Harold F. Dodge, Chairman
Eugene L. Grant
Ralph E. Wareham
A. E. R. Westman
S. S. Wilks

This Committee is authorized to study and select those symbols, concepts, nomenclature, procedures, and other matters which it feels the Society would find advantage in standardizing, and to make recommendations to the Board of Directors for such standardization by the Society.

SHEWHART MEDAL COMMITTEE APPOINTED

Announcement is made of appointment of the following Committee to administer the Shewhart Medal Foundation which was established by the Board of Directors in June, 1947:

Philip L. Alger, Chairman
Charles A. Bicking
Ernest L. Fay
G. Rupert Gause
Irwin S. Hoffer
Andrew I. Peterson

STANDING COMMITTEES

President Edwards has announced completion of all of the Standing Committees for 1947-48, excepting the Nominating Committee. They are constituted as follows:

Examining Committee
Paul A. Olmstead, Chairman
Martin A. Brumbaugh
Charles J. Hudson
Lloyd A. Knowler
Walter A. Shewhart

Committee on Professional Ethics and Qualifications
Charles J. Hudson, Chairman
S. Collier
Halsey H. Kent
Russell F. Passano
Hugh M. Smallwood

Auditing Committee
Howard L. Jones, Chairman
Howard R. Bolton
G. Rupert Gause
Paul A. Robert
Joseph Sadowski

Committee on Constitution and By Laws
Halsey H. Kent, Chairman
James M. Ballowe
Paul C. Clifford
John M. Howell
Ernest H. Robinson

GENERAL COMMITTEES

President Edwards has announced completion of four of the five General Committees for 1947-48, as follows:

Committee on Membership

Vice-President and General Chairman:
Frederick J. Halton, Jr.

Executive Chairman:
Jerome R. Steen

New England:
George J. Meyers, Jr., Regional Chairman
Dean Ayer
Robert R. Jones, Jr.
Paul E. Thorpe

Middle Atlantic:
Howard S. Clark, Regional Chairman
Lee Goulden
William J. Masser
John G. Rutherford
Richard L. Shire

Northern:
Howard M. Craig, Regional Chairman
L. E. Coger
Francis J. Haley
Evan J. Lewis
Edward A. Reynolds
George M. Wither

Central:
Jack L. Shafer, Regional Chairman
James B. Denmark
Fred E. Kindig

Mid-West:
Edward Don, Regional Chairman
Harold J. Cohan
Carl W. Helmstadter
E. K. Hoppe
Henry J. Jacobson
Frank A. Palumbo
Oliver L. Scott
W. A. Shideler

Western:
E. H. Bauer, Regional Chairman

Committee on Programs and Speakers

Vice-President and General Chairman:
Frederick J. Halton, Jr.

Executive Chairman:
Frank A. Palumbo

New England:
Gerald H. Cassady, Regional Chairman
Arnold B. Collins
Calvin J. Kirchen
Louis Rosenblum

Middle Atlantic:
Harry G. Romig, Regional Chairman
O. P. Bruno
Leo J. Jacobson
Charles R. Scott, Jr.
Silas Williams, Jr.

Northern:
John K. McKeigan, Regional Chairman
Edward R. Becker
Leonard D. Biles
Wilbur L. Burns
George A. Hunt
Walter S. Oliver

Central:
T. A. Squire, Regional Chairman
W. P. Cofield
Arthur S. Marthens

Mid-West:
Henry J. Becker, Regional Chairman
S. C. Amren
Emmet A. Boyer
E. J. Cade
Carl W. Helmstadter
Carl E. Hoover
Claude W. Lentfoehr
John E. Rahn, Jr.

Western:
Holbrook Working, Regional Chairman

Committee on Relations with Educational Institutions

Vice-President and General Chair-Chairman:
Frederick J. Halton, Jr.

Executive Chairman:
A. C. Richmond

Chairman, Sub-Committee on College Courses:
John A. Henry

New England:
Edwin A. Boyan, Regional Chairman
Morton M. Newcomb
C. H. W. Sedgewick
Dorian Shainin

Middle Atlantic:
Clifford C. James, Regionl Chairman
L. M. Arnett
Joseph A. Greenwood
John C. Hintermaier
Sebastian B. Littauer

Northern:
Andrew S. Schultz, Jr., Regionl Chairman
Howard W. Alexander
Howard R. Bolton
Alfred L. Davis
R. John D. Gillies
Washington Platt

Central:
Ralph A. Hefner, Regional Chairman
Frank G. Norris
R. S. Stainton

Mid-West:
John A. Henry, Regional Chairman
Niles Barnard
Charles S. Barrett
Irving Burr
Warren E. Jones
Howard A. Kibby
Lloyd A. Knowler
Walter A. Mollenhauer
Keith E. Ross

Western:
Eugene L. Grant, Regional Chairman

Committee on Relations with Other Technical Societies

Vice-President and General Chairman:
Frederick J. Halton, Jr.

Executive Chairman:
A. G. Ashcroft

New England:
Alfred Nielson, Regional Chairman
Edward Harrington
Leonard A. Seder
I. D. Skipp

Middle Atlantic:
Churchill Eisenhart, Regional Chairman
Gordon Cook
E. H. MacNiece
C. J. McClintock
George R. Page

Northern:
F. H. Thomas, Regional Chairman
Howard M. Craig
George E. Kenny
Emory M. Kurtz
Bernard H. Lloyd
Fred C. Nilson

Central:
C. Wells, Regional Chairman
William R. Marsden
G. M. Wentz

Mid-West:
Cameron E. Fisher, Regional Chairman
Niles Barnard
N. Bruner
Erwin G. Kressin
E. Russel Meyer
Ernest H. Robinson
Keith E. Ross
Carl G. Schmid

Western:
Henry Scheffe, Regional Chairman

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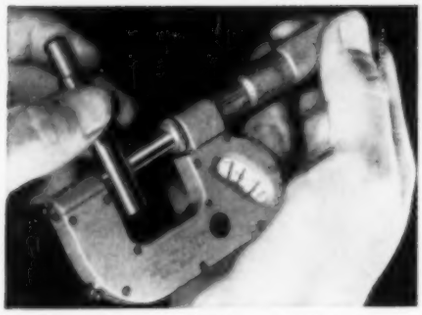
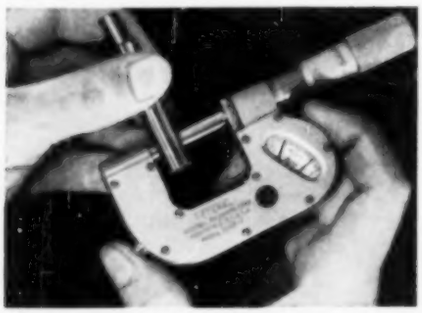


USED AS A MICROMETER — spindle is brought into contact until Indicator reads "O".



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